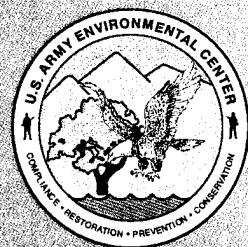


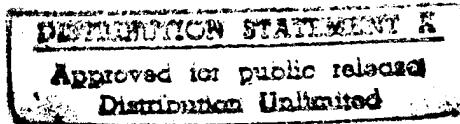
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**U.S. Army
Environmental
Center**

Report No. SFIM-AEC-ET-CR-96006
FINAL REPORT

Technical Support for Implementation of Aluminum Ion Vapor Deposition at Tobyhanna Army Depot



February 1996
Contract No. DACA31-91-D-0074
Task Order No. 0006

Prepared by:

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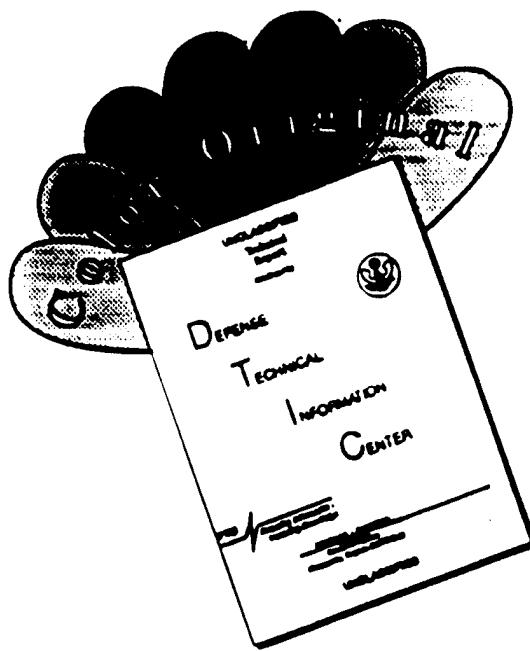
Prepared for:

U.S. Army Environmental Center
Aberdeen Proving Ground, MD 21010-5401

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Unclassified**Security Classification of This Page**

REPORT DOCUMENTATION PAGE				Form Approved OMB No. 0704-0188
1a. Report Security Classification Unclassified		1b. Restrictive Markings		
2a. Security Classification Authority		3. Distribution/Availability of Report Unlimited		
2b. Declassification/Downgrading Schedule				
4. Performing Organization Report Numbers(s) IT 322244		5. Monitoring Organization Report Number(s) SFIM-AEC-ET-CR-96006		
6a. Name of Performing Organization IT Corporation	6b. Office Symbol (if applicable) Cincinnati	7a. Name of Monitoring Organization U.S. Army Environmental Center (USAEC)		
6c. Address (City, State, and Zip Code) 11499 Chester Road Cincinnati, OH 45246		7b. Address (City, State, Zip Code) SFIM-AEC-ETD Aberdeen Proving Ground, MD 21010		
8a. Name of Funding/Sponsoring Organization USAEC	8b. Office Symbol (if applicable) SFIM-AEC-ETD	9. Procurement Instrument Identification Number Contract No. DACA 31-91-D-0074/006		
8c. Address (City, State, Zip Code) SFIM-AEC-ETD Aberdeen Proving Ground, MD 21010		10. Source of Funding Numbers		
		Program Element No.	Project No.	Task No.
				Work Unit Accession No.
11. Title (Include Security Classification) Technical Support for Implementation of Aluminum Ion Vapor Deposition at Tobyhanna Army Depot				
12. Personal Author(s) R. Hoye, R. Sinha				
13a. Type of Report Final	13b. Time Covered From 4/94 To 2/96	14. Date of Report (Year, Month, Day) 1996, February		15. Page Count 175
16. Supplementary Notation				
17. COSATI Codes		18. Subject Terms (Continue on reverse if necessary and identify by block number)		
Field	Group	Sub-group	Aluminum Ion Vapor Deposition AIVD IVD	
19. Abstract (Continue on reverse if necessary and identify by block number) Industrial production and maintenance activities conducted at Army depots typically include metal plating operations. For many years cadmium has been commonly applied as a surface coating using conventional electroplating processes to provide a protective, corrosion-resistant finish. Cadmium is a toxic, carcinogenic metal and cadmium electroplating generates sludges, rinse waters, and spent plating solutions that are hazardous wastes. Alternatives to cadmium electroplating exist. In many cases, aluminum coatings can be substituted for cadmium coating to provide corrosion protection and other functional requirements. Aluminum ion vapor deposition (AIVD) is a process that can be used to plate aluminum on metal parts. This technology, which was originally developed in the 1970s for use on aircraft parts, does not generate the hazardous wastes, rinse waters, sludges, or spent electrolyte solutions that are associated with conventional electroplating. With the exception of a small quantity of waste generated during periodic cleaning of internal components of the system, AIVD coating generates no wastes.				
20. Distribution/Availability of Abstract <input checked="" type="checkbox"/> Unclassified <input type="checkbox"/> Same as Report <input type="checkbox"/> DTIC Users		21. Abstract Security Classification Unclassified		
22a. Name of Responsible Individual Gene L. Fabian		22b. Telephone (Include Area Code) (410) 612-6847		22c. Office Symbol SFIM-AEC-ETD

19. Abstract (continued)

The USAEC provided technical assistance to Tobyhanna Army Depot (TOAD), located in Tobyhanna, PA, in regard to acquisition of an AIVD system. Site visits were conducted to TOAD, Anniston (ANAD), and to Corpus Christi (CCAD) Army depots. Both ANAD and CCAD use AIVD technology. The purpose of these visits was to discuss and review current cadmium plating operations and to document lessons learned regarding AIVD. Outputs of the technical support effort included Trip Reports, preparation of a Bid Specification for an AIVD system, an Economic Analysis (EA) for an AIVD system, a Work Order for installation of an AIVD system, and the collection of information on AIVD technology and coatings.

Report No. SFIM-AEC-ET-CR-96006

FINAL REPORT

**TECHNICAL SUPPORT FOR IMPLEMENTATION OF ALUMINUM ION
VAPOR DEPOSITION AT TOBYHANNA ARMY DEPOT**

February 1996
Contract No. DACA31-91-D-0074
Task Order No. 6

Prepared by:

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Prepared for:

U. S. Army Environmental Center
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ACKNOWLEDGMENT

This project was conducted by IT Corporation for the U.S. Army Environmental Center under Contract No. DACA31-91-D-0074, Task Order No. 0006. Mr. Gene L. Fabian of the USAEC's Environmental Technology Division (SFIM-AEC-ETD, APG, MD) served as the Project Manager for this Task Order which was titled "Hazardous Waste Minimization Technology Transfer/Implementation Support for Depot System Command Installations." Mr. Pat Tierney of the Production Engineering Division at Tobyhanna Army Depot (SDSTO-EM-H) provided information on depot plans and activities and served as the point of contact for the depot throughout the project. Mr. James Holiday and Mr. Joseph Crews provided information on aluminum ion vapor deposition (AIVD) operations at Corpus Christi and Anniston Army Depots, respectively.

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List of Acronyms

AIVD	Aluminum Ion Vapor Deposition
AMC	Army Materiel Command
ANAD	Anniston Army Depot
CCAD	Corpus Christi Army Depot
CFM	cubic feet per minute
CWA	Clean Water Act
ETD	Environmental Technology Division
DESCOM	Depot System Command
DoD	Department of Defense
EA	Economic Analysis
gpm	gallons per minute
HAZMIN	Hazardous Waste Minimization
Hz	Hertz
IVD	Ion Vapor Deposition
MIL SPEC	Military Specification
OSHA	Occupational Safety and Health Administration
psig	pounds per square inch
RCRA	Resource Conservation and Recovery Act
TOAD	Tobyhanna Army Depot
USAEC	U.S. Army Environmental Center
USEPA	U.S. Environmental Protection Agency
V	Volts

Executive Summary

Industrial fabrication and maintenance activities conducted at Army depots typically include metal plating operations. For many years, metal parts have been electroplated with cadmium. Cadmium surface coatings provide protection from corrosion and other desirable characteristics. However, cadmium is a toxic metal and electroplating generates significant quantities of wastes. These wastes, such as spent plating baths, sludges, and rinse waters are contaminated with cadmium and are regulated by the U.S. Environmental Protection Agency as hazardous waste under the Resource Conservation and Recovery Act (RCRA). Treatment of spent solutions and rinse waters in on-site industrial wastewater treatment plants also generates cadmium contaminated sludges that are also regulated as hazardous waste. Further, cadmium exposures in the workplace are regulated by the Occupational Safety and Health Administration (OSHA). Cadmium contamination in fumes, dusts, and mists, which commonly occur in industrial operations, is tightly regulated.

The inherent difficulties in safely handling toxic materials in the workplace and the increasing costs associated with management and disposal of hazardous wastes have become incentives for minimizing the generation of hazardous wastes and for pollution prevention at the source. Aluminum surface coatings can be substituted for cadmium in many applications. A technology developed in the 1970s, aluminum ion vapor deposition (AIVD), is a clean technology that can be used to apply coatings of aluminum to metal and other substrates including plastics and composites. Hazardous materials are not used in the process and essentially no wastes are generated. Aluminum surface coatings provide equal or greater corrosion protection as compared to cadmium and offer other beneficial characteristics as well. Two Army depots (Anniston and Corpus Christi) have successfully implemented this plating technology. Other military and commercial operations also use aluminum ion vapor deposition as well.

The U.S. Army Environmental Center (USAEC) supports waste minimization and pollution prevention initiatives at Army depots by conducting research, development, and demonstration

projects. This report documents technical support that was provided to the Tobyhanna Army Depot (TOAD) by the USAEC to support implementation of AIVD technology. Information on the technology, its advantages, and disadvantages was acquired and evaluated. Project outputs include a detailed Bid Specification, an Economic Analysis, and a Work Order. Each of these documents, included as appendices to this report, were prepared in the format specified by TOAD to facilitate their use and implementation. Currently, TOAD is initiating the acquisition process for an AIVD system.

1.0 Introduction

The Environmental Technology Division (ETD) of the U.S. Army Environmental Center (USAEC) conducts research and development to support environmental compliance at Army depots, ammunition plants, arsenals, and other Army installations and activities where industrial manufacturing and maintenance is conducted. Since the outset of the U.S. Army Materiel Command's (AMC) hazardous waste minimization (HAZMIN) program, the USAEC has been an active supporter of HAZMIN initiatives at all AMC industrial operations. Previous initiatives relating to U.S. Army Depot System Command (DESCOM) facilities have included the demonstration and implementation of aluminum ion vapor deposition (AIVD) at Anniston Army Depot (ANAD)¹. Subsequent to the successful application of AIVD at ANAD, Corpus Christi Army Depot (CCAD) also implemented the use of AIVD technology. Most recently, the USAEC provided support for technology transfer and implementation of AIVD at Tobyhanna Army Depot (TOAD). The technical assistance provided to TOAD is the focus of this report.

1.1 Background

Industrial production and maintenance activities conducted at Army depots typically include metal plating operations. For many years, cadmium has been commonly applied as a surface coating, using conventional electroplating processes, to provide a protective, corrosion-resistant finish. Cadmium plating offers good corrosion resistance in salt-water environments, provides a good base for soldering, and has a low coefficient of friction that gives cadmium-plated fasteners good threaded connections with low applied torque.¹ Cadmium, however, is a toxic, carcinogenic metal and cadmium electroplating generates sludges, rinse waters, and spent plating solutions. These residuals contain cadmium and are listed hazardous wastes under the Resource Conservation and Recovery Act (RCRA). Treatment of the rinse water and spent solutions also generates sludges that are RCRA hazardous waste and that require special handling and disposal.

Alternatives to cadmium electroplating exist. In many cases, nonhazardous aluminum coatings can be substituted for cadmium coating to provide corrosion protection and other functional requirements. Aluminum can be applied by metal spraying, cladding, electroplating, or ion plating.² Aluminum ion vapor deposition (AIVD) is a process that can be used to plate aluminum on metal parts. This technology, which was originally developed in the 1970's for use on aircraft parts, does not generate the rinse waters, sludges, or spent electrolyte solutions that are associated with conventional electroplating. With the exception of a small quantity of waste generated during periodic cleaning of internal components of the system, AIVD coating generates no wastes.

Previously, the USAEC conducted a demonstration of AIVD technology at the Anniston Army Depot (ANAD) where a full scale production system was installed.¹ Currently, this system and a second AIVD system, added after USAEC's demonstration to increase productivity, are in use at ANAD. Another system is being operated at the Corpus Christi Army Depot (CCAD). At each depot, AIVD coatings have been successfully substituted for cadmium electroplated coatings on a variety of metal parts. Substitution of AIVD coatings for cadmium electroplated coatings can significantly reduce the volume of RCRA hazardous wastes that are generated by Army depot operations. Their use also reduces employee exposures to cadmium and other toxic components (e.g. cyanide and corrosive solutions) that are used in the conventional electroplating process.

Multiple regulatory incentives for substitution of cadmium coatings exist and are summarized in the draft "Strategic Plan for Eliminating Cadmium from United States Army Tactical Weapon Systems" prepared by the Army Acquisition Pollution Prevention Support Office.³ The laws, regulations, and policies that impact the use of cadmium include:

- National Environmental Policy Act,
- DoD Directive 4210.15, "Hazardous Materials Pollution Prevention,"
- DoD Directive 5000.1, "Defense Acquisition Program Policy, Guidelines, and Management Responsibilities,"

- DoD Instruction 5000.2, "Defense Acquisition Management Policies and Procedures,"
- DoD 5000.2-Manual, "Defense Acquisition Management Documentation and Reports,"
- Army Regulation (AR) 200-1, "Environmental Protection and Enhancement,"
- Army Regulation (AR) 200-1, "Environmental Effects of Army Actions,"
- Executive Order 12856, "Federal Compliance with Right-to-Know Laws and Pollution Prevention Requirements,"
- Executive Order 12873, "Federal Acquisition, Recycling, and Waste Prevention,"
- OSHA Cadmium Standard (Title 29 CFR, Part 1910.1027),
- Resource Conservation and Recovery Act,
- Clean Water Act and Amendments,
- Clean Air Act and Amendments,
- Pollution Prevention Act,
- Various State Laws.

Regulation of cadmium usage and contamination has become increasingly more restrictive. This trend is expected to continue in the future. Increasing costs and increasing impediments to plating operations are associated with more stringent regulation. Implementation of alternatives to cadmium electroplating is being actively pursued by the Army to minimize the generation of hazardous waste and to ensure protection of worker's health and the environment.

1.2 Scope and Objective

The scope of the work documented herein was focused on providing technical assistance to Tobyhanna Army Depot (TOAD), located in Tobyhanna, PA, in regard to acquisition of an AIVD system. Information acquisition efforts included completion of site visits to ANAD and CCAD to discuss and observe the operation and use of AIVD in depot operations. Site visits to TOAD were also conducted to discuss and review current cadmium plating operations. The plans and schedule

for acquisition of AIVD technology were discussed and tours of the industrial facility, including the planned location for the AIVD system, were conducted.

Outputs of this technical support effort included Trip Reports, a Bid Specification for an AIVD system, an Economic Analysis (EA) for an AIVD system, a Work Order for installation of an AIVD system, and the collection of information on AIVD technology and coatings. Due to changes in the Army's schedule for funding and acquisition of an AIVD system, the system was not purchased by TOAD during the project as originally planned. The information presented in this document and the attached appendices is intended to serve as background and guidance information for depot personnel at TOAD, or other interested facilities, during the evaluation and acquisition of AIVD plating technology as a replacement for cadmium electroplating.

2.0 Cadmium and Aluminum Coatings

2.1 Electroplated Cadmium Coatings

Cadmium is a soft, ductile, silver-white metal.⁴ Electroplating of elemental cadmium onto the surface of metal (e.g., fabricated steel and cast iron) parts has been commonly practiced by commercial industry and the military for over 50 years. Cadmium coatings offer excellent corrosion resistance in salt water environments and extend the life of metal components, such as those constructed of high strength steels. In addition to corrosion resistance, cadmium's natural lubricity enhances its use on threaded fasteners. It is also readily solderable and serves as a good substrate for finish coatings (e.g., chromate conversion coatings and paint finishes). Cadmium's ease of electroplating and high deposition rates combined with the desirable characteristics of this coating material have resulted in the widespread use of this surface plating technology.⁴ Electroplated cadmium coatings have been used on components of military equipment for many years and numerous military specifications for metal parts require the use of cadmium coatings.

Cadmium electroplated coatings are typically applied to metal parts at Army depots to provide one or more of the following performance parameters at reasonable life cycle costs:³

- corrosion control in marine and industrial atmospheres
- corrosion control on complex parts in natural atmospheres
- corrosion control when applied in a thin (i.e., 0.2 to 1.0 mil) layer
- a sacrificial coating that minimizes hydrogen embrittlement in high strength steels
- galvanic compatibility between aluminum and steel components
- a lubricous surface that does not gall or bind under load
- a paintable surface

- an aesthetically appealing, corrosion-free surface on parts that will be stored for extended time
- effective corrosion control without voluminous corrosion products

Requirements for electrodeposited cadmium coatings are specified in MIL SPEC QQ-P-416E, February 1987.⁵

Cadmium electroplating is typically carried out in an aqueous bath of cadmium oxide and sodium cyanide. Other electrolytes include cadmium sulfate, sulfamate, chloride, fluoroborate, and pyrophosphate.⁶ Cadmium fluoroborates are used for electroplating high strength steels. The part being plated serves as the cathode in the electrolytic cell and the cadmium solution serves as the electrolyte. Plating operations at Army depots typically involve relatively large (e.g., 4 ft wide by 10 ft long by 4 ft deep) open top plating tanks. Smaller tanks are also used to handle small parts or where production throughput is limited. Push-pull ventilation systems are typically used to remove fumes from the plating shop.

Parts are cleaned prior to plating by mechanical (e.g., grit blasting and sanding) and/or chemical means, (e.g., vapor degreasing, chemical paint stripping, and chemical stripping of existing electroplates) then connected to busbars and lowered into the electrolyte. The time required for plating depends upon desired thickness and operational parameters including applied current and solution chemistry. Parts are subsequently rinsed in water and then treated, typically by applying a chromate conversion coating, and subsequently painted. At TOAD the typical sequence of cadmium plating operations is: ultrasonic cleaning, caustic dip, hydrochloric acid dip (to strip old cadmium coatings), cadmium electroplating, chromate conversion coating, and finish painting.⁷ Water rinses are conducted between several of these operations.

Cadmium is a toxic metal and proper handling of the metal and industrial residues is required. Acute industrial poisoning can occur through the respiration of cadmium dusts or fumes during common operations such as melting, welding, or heating of cadmium-plated steel.⁴ Regulation of cadmium

in the workplace and in the environment has continued to become increasingly more stringent. For example, until 1992 the Occupational Health and Safety Administration (OSHA) regulations set the permissible exposure limit (PEL) for cadmium at $100 \mu\text{g}/\text{m}^3$ in workplace breathing air. In 1992 this limit was reduced to $5 \mu\text{g}/\text{m}^3$, a 95 percent reduction.³ The OSHA standard includes requirements for engineering controls, medical monitoring and record keeping, respirator use, and worker training.

Cadmium can contaminate the workplace at Army depots through a variety of sources related to cadmium electroplated surfaces. Cadmium solutions and fumes must be managed during the electroplating operation. Dragout of cadmium on plated parts contaminates rinse waters, which require subsequent treatment prior to discharge. The sludges generated at the wastewater treatment plant also become contaminated with cadmium. Additionally, exposure can also occur during the handling of cadmium plated parts during repair and maintenance activities. Stripping of surface coatings, including cadmium electroplates, is accomplished by both physical and chemical means. These operations generate cadmium contaminated residuals such as spent shot blast media and chemical stripping solutions and sludges. Management and disposal of cadmium containing wastes and residuals is regulated by the U. S. Environmental Protection Agency (USEPA) under the hazardous waste regulations of the Resource Conservation and Recovery Act (RCRA) and under the Clean Water Act (CWA).

Increasingly more stringent requirements stipulated by environmental and health protection regulations have resulted in increasing costs associated with cadmium electroplating. Both the current costs associated with meeting requirements, such as those for waste management, transport and disposal, medical monitoring, record keeping, preparation of manifests, and those which may be associated with potential future liabilities resulting from disposal of hazardous wastes, have impacted the use of this process. It is anticipated that tighter regulatory restrictions and increasing costs associated with meeting these environmental and health related restrictions will continue for the foreseeable future. Methods to minimize the wastes generated and engineering controls to enhance workplace safety must continue to be employed and expanded.

State-of-the-art environmental control technology for cadmium electroplating is a closed-loop system.¹ In an example of a closed loop system, electroplating solutions are filtered to remove solids and passed through a bed of activated carbon to remove degraded organic brighteners and other organic contaminants. Refrigeration of the solution can be used to precipitate sodium carbonate produced by the oxidation of sodium cyanide. The treated solution is then brought back to specification by addition of sodium cyanide, brighteners, additives, water, and/or other ingredients as required. Rinse waters can be treated by reverse osmosis. Although a closed-loop system recycles the solutions, cadmium contaminated wastes are generated (e.g., spent carbon, precipitated sodium carbonate, filterable solids, etc.). Sustained operation of a plating operation as a totally closed loop with zero discharge is not anticipated to be achievable.⁴ Generation of some waste (sludges, liquids, or gaseous emissions) is inherent to these solution electroplating operations.

Plating solutions have a finite life span and disposal of spent solutions is a major source of cadmium wastes. The useful life of plating solutions can be extended through reducing drag-out and the resultant loss of active plating chemicals, reducing contamination of the plating bath from chemicals used for parts cleaning, and/or purification of the plating solution (e.g., through the use of ion exchange, osmosis, or electrodialysis). Cadmium wastes will nonetheless be generated at some point. The most effective control is process substitution and elimination of most or all of the cadmium electroplating conducted at Army depots.

2.2 Ion Vapor Deposition Aluminum Coatings

Aluminum is a soft, light, odorless, tasteless, nontoxic, nonmagnetic, and highly conductive metal.⁴ It is the most widely used nonferrous metal because of these and other favorable characteristics. In particular, the formation of a thin, tightly adherent, oxide film provides excellent corrosion resistance.⁴ Aluminum coatings can be applied by metal spraying, cladding, electroplating, and ion deposition.² The ion deposition process is advantageous because of the control of thickness that it affords. Additionally, ion plated coatings typically have good adhesion and are applied at low substrate temperatures (90-150° F).² "Throwing power," the ability of the process to coat complex shaped parts, is another strong point of ion vapor deposition.² The main benefits of aluminum

coatings as a substitute for cadmium are that they can provide better corrosion protection while avoiding both worker exposure to toxic metals and the generation of hazardous wastes.⁸ Advances in vacuum coating technology has significantly increased its competitiveness with conventional electroplating.⁹

In the 1970's, a technology was developed by the McDonnel-Douglas Aircraft Company for the ion vapor deposition (IVD) of aluminum (herein referred to as aluminum ion vapor deposition, AIVD) to apply a uniform, dense and highly adherent coating of aluminum.² Since its development, AIVD systems have been installed and operated at over 70 facilities, including both government/military and commercial (both job shop and captive shop) applications. Two Army depots, ANAD and CCAD, currently use AIVD systems to at least partially replace cadmium with aluminum coatings. During completion of this project, both ANAD and CCAD were visited to observe and discuss lessons learned during application of AIVD plating at Army depots (Appendices A and B). In addition to military applications, several commercial plating shops provide AIVD coating services.¹

The Navy uses this technology at both Jacksonville and Pensacola Naval Air Stations. The Air Force confirmed that substitution of AIVD coatings met or surpassed all requirements during testing of parts from multiple Air Logistics Centers by the McDonnell-Douglas Aircraft Company.⁹ Air Logistics Centers, including Warner Robins, Ogden, Oklahoma City, and Sacramento, operate AIVD systems for coating of aircraft parts and are converting their cadmium plating workload to AIVD coatings. It is anticipated that about 80 percent of the cadmium work load can be converted.⁸ Parts that are too large, or that have deep recesses, are not candidates for AIVD coating and remain part of the workload for cadmium plating lines at these ALC's. Additionally, the bonding of the coating to the substrate and the columnar structure of the AIVD deposit help reduce problems with fatigue.² This nature of the coating also reduces problems associated with differences in coefficients of expansion of the coating and the substrate.²

AIVD coatings are also applied during production, as opposed to overhaul and maintenance operations. For example, AIVD is the prime coating used on components of the Patriot, Amraam, and Lantirn projects.¹⁰ Other specialized applications of AIVD coatings include coating of ferrite assemblies on the Patriots phased array radar system.¹⁰ The conductivity of aluminum allows it to be used for electrical bonding and for EMI and RFI shielding.¹⁰ Most recently, AIVD has been used to coat plastics and composites.⁶ CCAD has successfully plated plastic components by making some modifications to the operating process and sequence. AIVD coating of permanent Neodymium Iron Boron (NdFeB) magnets is a recently developed application that can provide corrosion protection and unlike conventional electroplates, the AIVD coating exhibits good adhesion in this new application.¹⁰

Military Specification MIL-C-83488C establishes the requirements for coating low alloy steel, stainless steel, aluminum alloy and titanium alloy parts with high purity (99 percent plus) aluminum.¹¹ Three classes of coatings, Class 1, 2, and 3, having minimum coating thickness of 1.00, 0.50, and 0.30 mils, respectively, are specified. This MIL SPEC also requires that the coating provide corrosion protection as tested in a 5 percent salt spray cabinet. Based on the specified salt spray test requirements aluminum provides significantly greater corrosion resistance than cadmium for coatings of the same thickness. The MIL SPECS reflect these differences. For example, a 0.5 mil coating of cadmium must provide 96 hours of resistance (determined by formation of white corrosion products or corrosion of base metal) without a chromate conversion coating and 168 hours with a conversion coating.⁵ The same thickness of aluminum must provide 336 hours of protection without conversion coating and 504 hours with the chromate coating (without evidence of base metal corrosion).¹¹

AIVD generally produces a consistent coating thickness.² The consistency and thickness of the coating in deep recesses or the interior of holes is difficult to control.¹⁰ Variations in the thickness of the coating associated with the relative position of the parts in the chamber can thus occur during a single plating run.¹² Aluminum coatings are applied in recesses or bores to a depth approximately equal to the diameter. The coating typically loses uniformity and thickness at a depth exceeding

0.5 diameter.¹⁰ The AIVD coating, as deposited, has significant microporosity that is a result of the way in which aluminum accumulates on the surface during plating. The AIVD coatings must be densified by peening (burnishing) with glass beads to consolidate the coating.¹² Porous coatings break down more quickly, provide less protection from corrosion, and potentially can cause hydrogen embrittlement of high strength steel substrates.¹³ Several major advantages of AIVD coatings are summarized in Table 2-1. Several potential disadvantages are summarized in Table 2-2.

A higher torque is usually required to install an AIVD coated fastener than a cadmium coated fastener because of aluminum's higher coefficient of friction.² Torque-tension relationships have been a concern of the aerospace industry for flight-critical fasteners. As a result of this concern, AIVD coatings have been subjected to rigorous testing and evaluation. McDonnell-Douglas evaluated the use of various lubricants on AIVD fasteners to reduce the required torque. The use of a cetyl alcohol lubricant can reduce torque requirements by up to 70 percent.^{2,9} In addition, this concern led to the development of aluminum-teflon paints.² AIVD coated fasteners have been used in aerospace applications for nearly 15 years. Very few reports of problems related to the torque-tension issue have been reported.² In general, it has been found that the use of a lubricant has been adequate and that the differences have not been sufficient enough to warrant changes in installation procedures, tools, or hole sizes.²

While AIVD processing is a technologically advanced system, the degree of operator competence required is similar to that of conventional cadmium electroplating. ANAD and CCAD have found that the systems are well received by plating shop personnel and that existing personnel could be readily trained and become productive and efficient AIVD operators.

Table 2.1 AIVD Offers Several Advantages Over Cadmium Electroplating

- Generates essentially no wastes
- Avoids employee exposures to hazardous materials including Cd, caustic plating solutions, cyanides, etc.
- Reduces loadings to wastewater treatment plants, as no effluents are generated
- Environmental permits are not required
- Outperforms Cd coatings in preventing corrosion in acidic environments
- Coatings can be used in high temperature service (925°F vs 450°F for Cd)
- Aluminum can be used in contact with titanium without solid metal conversion problems
- Can be used in contact with fuels
- Permits thicker coatings (several mils) compared to electroplated Cd (~1mil)
- Provides better uniformity of coating on edges and corners than solution electroplating

Reference No. 6

Table 2.2 AIVD is not a Universal Replacement for Cadmium and Some Disadvantages Exist.

- AIVD is not a universal substitute for Cd electroplating; applicability must be assessed for each part
- Difficult to coat interiors of blind holes and cavities where depth exceeds diameter
- Aluminum has a higher coefficient of friction than Cd, therefore changes torque tension relationships for fasteners
- Unlike Cd, AIVD coatings cannot be combined with Ni to provide a more erosion-resistant surface
- No simple way to repair damaged AIVD coatings
- AIVD can be slower than Cd electroplating (However, AIVD coatings on high strength steels do not require time consuming hydrogen embrittlement relief treatment)
- AIVD coatings must be peened (burnished) with glass beads to densify coating (an additional parts handling step)

Reference No. 6

3.0 AIVD Processing

3.1 Equipment and Operation

Currently, two equipment vendors provide AIVD systems: Abar Ibsen and IVI Corporation. The systems are similar in function and appearance. The following description is generic and representative of both systems. Major components of the system include the vacuum chamber, vacuum pumps (a roughing pump, a mechanical pump, and a diffusion pump), parts handling equipment (e.g., dollies, racks, barrel coaters, etc.), and a computer controller. Although the system can be operated manually, computer controllers facilitate use and increase production efficiency.

The production area should be clean and air conditioned as the presence of contamination and humidity greatly increase pump down times and can affect the quality of the coating. A separate, positive pressure room which the AIVD chamber opens into, is typically constructed to house the parts handling and operator control area. Although size of the work area can be varied, sufficient room to allow the use of multiple parts racks and dollies increases productivity. Floorplans and photographs of AIVD systems installed at ANAD and CCAD are included in Appendices A and B.

AIVD is conducted in a cylindrically shaped vacuum chamber constructed of mild steel. The internal size of a standard chamber is approximately 6 ft in diameter by 12 ft long. This yields a usable plating zone of approximately 5 by 10 feet.² Smaller chambers are available for special applications or where throughput or part size doesn't require a full size system. The cost of a smaller system is not reduced in proportion to the reduction in physical size. Reducing the chamber size also reduces the capabilities of the system in terms of the number and types of parts that can be plated. System utilities include electricity (e.g., 480 V, 3 Phase, 60 Hz, 300 amp service), argon gas (compressed cylinder supply), non-contact cooling water (~25 gpm at 40 psig)

and gaseous nitrogen for the cryogenic pump, and compressed air (60 - 80 psig) to operate vent valves and air ride dollies. Ancillary equipment, such as glass bead peening booths and grit blast booths require compressed air (e.g., 70 cfm at 80 psig) and electricity (460 V, 3 phase, 60 Hz, 3 amps and 110 V, 1 phase, 60 Hz, 6 amps). Complete utility requirements for an AIVD system are specified in the Bid Specification and Work Order presented in Appendices F and H.

Once existing paint and surface coatings have been stripped, degreasers or ultrasonic cleaners can be used to clean parts. Surface contamination, including rust, mill scale, and residues of cleaning, can affect the quality of the AIVD coating including reduced adhesion and less corrosion protection.¹² Subsequent to cleaning, the parts are dry blasted with aluminum oxide (150 - 220 mesh) to prepare the surface for plating.⁹ Cleaned parts to be plated are hung from a rack which is then slid into place in the chamber. Because the surface of the parts must be clean and free of surface contamination, operators typically wear cotton gloves to avoid transfer of skin oils to the parts. Cleaned parts should be plated within 4 to 6 hours of cleaning to avoid contamination.

The manner in which the parts are positioned on the parts rack and therefore how they are positioned in the plating chamber is an important operating parameter. The number of parts plated during a cycle and their relative positions and orientation, can affect plating thickness and quality. To facilitate parts loading, specialized dollies are supplied by the manufacturer. Air flotation pads on the legs allow the parts racks to be easily moved. Additionally, the dollies are constructed to allow the large racks to slide easily from the dolly into the chamber and to be easily removed after plating. In addition to these standard racks and dollies, specialized parts racks (including rotating racks) and barrel coaters are available or can be constructed. The use of air ride dollies necessitates that the shop area have a flat, smooth floor.

A mechanical pumping system consisting of three-stage diffusion pumps backed by rotary vane and booster pumps are used to achieve the 9×10^{-6} torr operating vacuum.¹⁰ To decrease pump down times, a cryogenic cooler can be used to remove water vapor present in the chamber. The pumps and blower are used to evacuate the chamber, while the cryogenic cooler removes moisture

from within the chamber to reduce pump down time. Humidity in the chamber severely impacts pump down time. Therefore, the front end of the chamber is located in an air conditioned room. This allows control of humidity and helps to minimize contamination of the parts prior to coating. The only discharge from the system is the exhaust from the vacuum pumps. A single 4-inch diameter PVC vent pipe is used for this purpose. This is the sole discharge from the system. Environmental permits were not required for installation and operation of the systems at ANAD or CCAD.

Once parts have been loaded into the chamber and the vacuum (10^{-6} torr) achieved, argon gas is introduced to raise the pressure to about 6×10^{-3} torr. A high-voltage negative potential is applied to the substrate, which generates a plasma within the chamber. The bombardment of the surface by argon ions provides a final cleaning of the parts and is characterized by a distinctive light discharge and increase in current.¹⁰ This process is continued for 10 to 20 minutes.

To initiate plating, aluminum wire is fed to seven ceramic boats that are electrically heated to 2000° F. The wire vaporizes and is deposited on the surface of the parts hung in the chamber. The boats are mounted on a motorized, movable rack which traverses the length of the chamber and back. The number of passes made by the boat rack, the speed of the ceramic boats, and the feed rate of the aluminum wire are critical operating parameters that affect coating thickness, consistency, and quality. While AIVD plating is not a strict line-of-sight process, the distance between parts and between the parts and the boats and their relative orientation can affect the thickness and consistency of the coating. Therefore, placement of parts is also a critical parameter that must be controlled by the operator. Depending upon the complexity of their shape, the parts may have to be turned and the plating process repeated to ensure complete coverage. Alternately, rotating racks may be used to move the parts during plating. Depending upon the operating parameters and the level of humidity in the chamber, pumpdown and plating can take 1 to 2 hours.

A cool down period of about ten minutes follows completion of the plating process (i.e., completion of the predetermined number of passes of the boats). The chamber is then vented to

return to atmospheric pressure and the chamber door is opened. The parts rack is transferred to an air ride dolly and removed from the chamber. At this point, the AIVD coating is porous, due to the columnar structure associated with the plated aluminum.⁹ This porosity is reduced and the coating densified by peening (burnishing) the surface with glass beads at 20 - 30 psi in a glove box or blast booth.¹⁰ The peening also ensures that proper adhesion of the coating to the substrate was achieved. If, due to surface contamination for example, the adhesion of the coating is inadequate, the peening process will result in removal of the coating. Coating failure of this type would necessitate that the parts be stripped, cleaned, and re-coated.

3.2 Waste Generation

Removable stainless steel liners (thin panels) are used to avoid coating of internal components of the chamber with aluminum. The liners must be periodically removed and cleaned, either by mechanical or chemical stripping, to remove accumulations of aluminum. The panels also serve to reduce the time required to pump down to vacuum. If the accumulations of aluminum are not removed periodically, their porous nature will trap gases and moisture, which will then off gas during pump down. This can significantly increase the time required to achieve the working vacuum. The panels can be stripped chemically, for example by dipping in a sodium hydroxide solution, which generates a caustic residue. This residue is a RCRA characteristic hazardous waste (corrosive) and is the only waste stream directly associated with the AIVD process. Because the depots typically have a sodium hydroxide dip tank as part of their conventional plating operations, this residue is not a new or additional waste. Alternatively, the aluminum removed from the shields can potentially be recovered and recycled, though not directly back to the AIVD process.¹⁴ The frequency of cleaning is dependent on production rates and is indicated by noticeable increases in pumpdown times. The volume of this waste stream varies with the workload put through the AIVD system.

Other wastes are generated during pre- and post-treatment of parts plated by AIVD. These treatments are the same treatments commonly used in conventional cadmium electroplating (e.g., degreasing, stripping of existing paint and surface coatings, grit blasting, chromate conversion

coating, and finish painting). While such waste streams are not avoided through the substitution of AIVD for cadmium electroplates, they would not become contaminated with cadmium in the case of complete substitution. The pre-treatment of parts during overhaul and maintenance will continue to generate cadmium contaminated residues after implementation of AIVD coating until all cadmium parts are returned from the field, cycled through the maintenance system, and plated with AIVD coatings.

3.3 Cost

The cost of an AIVD system is dependent upon a number of variables including system options, manufacturer, delivery distance, and other factors. In addition to the capital cost associated with the purchase of the AIVD equipment, costs will also be incurred for the preparation of the plating shop. Site preparation typically will include construction of an air conditioned clean room with a smooth, flat floor that can accommodate the weight of the system and production parts. Estimated AIVD system costs are presented in Table 3-1. Total equipment cost for a standard size AIVD system is anticipated to be in the range of \$680,000 to \$780,000, based on information obtained from ANAD, CCAD and AIVD equipment vendors. The delivery time for an AIVD system can be anticipated to be in the range of 24 to 36 weeks.

Although the direct capital and operating costs for an AIVD system are higher than those for conventional cadmium electroplating.⁶ The benefits to the life-cycle costs achieved by the avoidance of hazardous waste generation, worker exposure to toxic metals and corrosive solutions, and the need for ventilation and fume control, at least partially offset this differential. The cost differential is anticipated to continue to decrease in the future as cadmium plating becomes increasingly more expensive due to increasingly stringent environmental and health regulations. Advances in vacuum plating technology, which increase productivity and reduce cost, are also likely to continue as the use of this technology expands.

TABLE 3.1 Estimated Range of Costs for an AIVD System

Item	Estimated range, \$
AIVD System (6 by 12 ft chamber)	\$480,000 - \$510,000
Parts racks/dollies (2)	\$44,000 - \$46,000
Barrel coating rack	\$40,000 - \$42,000
Cryogenic pump	\$32,000 - \$40,000
Shipping, installation, training, and spare parts	\$20,000 - \$70,000
Pressure glove boxes	\$15,000 - \$25,000
Site preparation	\$50,000 - \$50,000
Total	\$681,000 - \$783,000

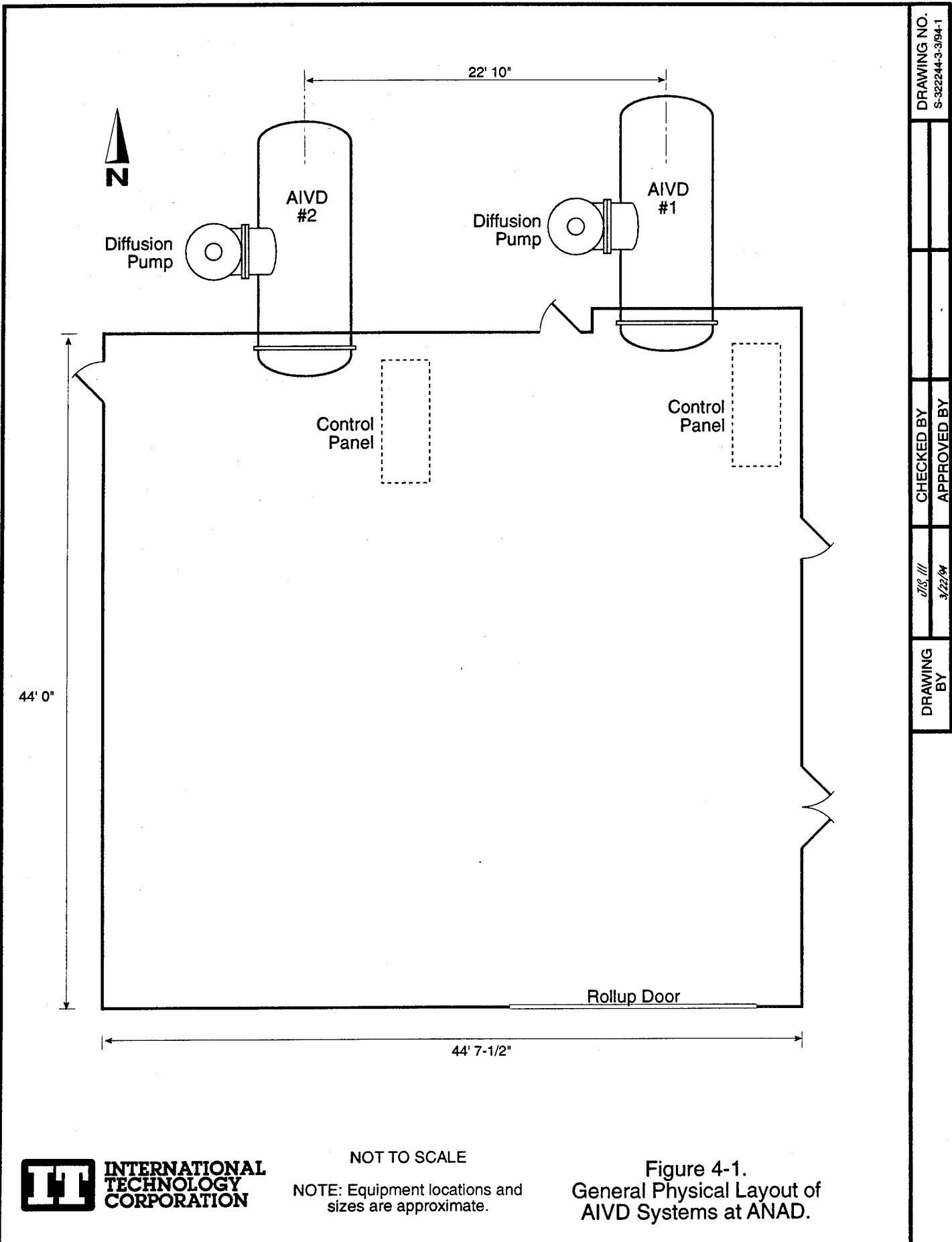
4.0 AIVD Plating Operations at Army Depots

During the course of the technical assistance provided under this project, site visits and meetings were held at ANAD, CCAD, and TOAD. The purpose of this activity was to obtain information on the success of implementation of AIVD technology at ANAD and CCAD and to obtain information on lessons learned that could benefit implementation at TOAD. A brief summary of the information acquired during the visits is presented below. Trip reports prepared subsequent to each visit are included in Appendices A (ANAD), B (CCAD), and C (TOAD).

4.1 ANAD

An AIVD plating system was first installed at ANAD in early 1991 under a previous USAEC demonstration project.¹ Subsequently, a second system has been installed to increase production capabilities. Both systems were obtained from Abar Ibsen Industries of Bensalem, Pennsylvania and are co-located in a common shop area. Aluminum coatings are applied to various vehicle and engine parts. ANAD is a rebuild/maintenance center for the Army Tank Automotive Command. Use of the AIVD systems varies with production levels. A schematic layout of the ANAD AIVD facility is shown in Figure 4-1.

Although the original unit did not include a cryogenic cooler, it has since been retrofitted with one. The bid specification used for the acquisition of the second AIVD unit required a cryogenic cooler. This system component reduces pump down time to approximately 30 minutes and is seen as a critical element for efficient operation. Standard air flotation dollies supplied by the manufacturer are used to hold and move the large parts racks. Multiple dollies and racks were purchased to enhance productivity. The use of multiple dollies and racks allows the operators to load and/or unload parts during AIVD plating cycles. The size of the shop must take into account the number of dollies and parts racks that will be used and must allow room to maneuver them to and from the chamber.



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The plating process at ANAD includes pretreatment consisting of vapor degreasing, chemical stripping of existing cadmium or aluminum coatings and, abrasive blasting with aluminum oxide. The blast booths (glove boxes) used for the abrasive aluminum oxide blasting are dedicated for use on parts that will be plated by AIVD (i.e., pretreatment of parts is segregated to avoid contamination of parts with residuals that could affect the AIVD coatings). Subsequent to completion of the AIVD coating cycle, aluminum coated parts are peened (burnished at 20 - 30 psi) with glass beads in dedicated blast booths (glove boxes). The parts then receive a conventional chromate conversion coating.

Depot personnel have modified the parts racks, through the addition of fixed eye bolts and alligator clips, to facilitate the placement and removal of parts. Additionally, operators initiated treatment of the protective shields with boron nitride.¹ This treatment serves as a release agent, making removal of aluminum accumulations much easier.

During start-up of the new system, the equipment vendor supplied two weeks of onsite operator training as part of the purchase. Five ANAD operators were trained in the operation of the AIVD units. Subsequent to installation, start-up, and training, approximately six months of testing and evaluation were required to adequately define operating methods and parameters that produced the desired coating thickness and consistency on the specific parts plated.

Lessons learned at ANAD indicate that both a cryogenic cooler and a computer controller should be included in the equipment bid specifications for any new AIVD system. Operator training, multiple parts racks and dollies should also be incorporated to maximize the efficiency of startup and operation. Finally, dedication of pre- and post-treatment equipment (e.g., blast booths/glove boxes) was recommended to help minimize contamination of parts which can result in inadequate coatings.

4.2 CCAD

An AIVD system was installed at CCAD in early 1993 and has been successfully used in plating operations since that time. The system was supplied and installed by IVI Corporation of Pembroke, Massachusetts. A schematic layout of the system is shown in Figure 4-2. With the exception of its automated computer controller (Intel 486 based), the CCAD system is very similar to those in operation at ANAD in both appearance and function. This controller is programmed to control all operational parameters including pump down, argon cleaning, the number of passes and the speed of the ceramic boats, and the aluminum wire feed rate. The controller has also been programmed to permit initiation of an automatic startup sequence which initiates warmup of the system prior to start of the production shift. This significantly reduces the initial startup time for the operators. The operating parameters associated with specific parts, including the number of parts and their specific placement on the parts racks, can be entered into the system's data base. This historical information assists the operator in ensuring that consistent coatings are applied.

Standard air floatation dollies are used at CCAD. As at ANAD, CCAD operators have made modifications to the parts racks that facilitate parts handling. The addition of eye bolts, fixed in strategic locations on the rack, speed the loading and unloading operations for commonly plated parts. This modification also helps avoid electrical short circuiting that can occur if parts touch or are not properly attached to the rack.

Lessons learned at CCAD confirm that a cryogenic cooler and a computer controller (including a color monitor and 24-pin narrow carriage printer) should be included on any new system. Operator training by the equipment vendor should be included in the purchase package. CCAD operators recommend that a week of initial training be completed prior to actual use. After a month of operating experience is gained, a second week of training is recommended to enhance operator skills and to address problems encountered during initial operations.

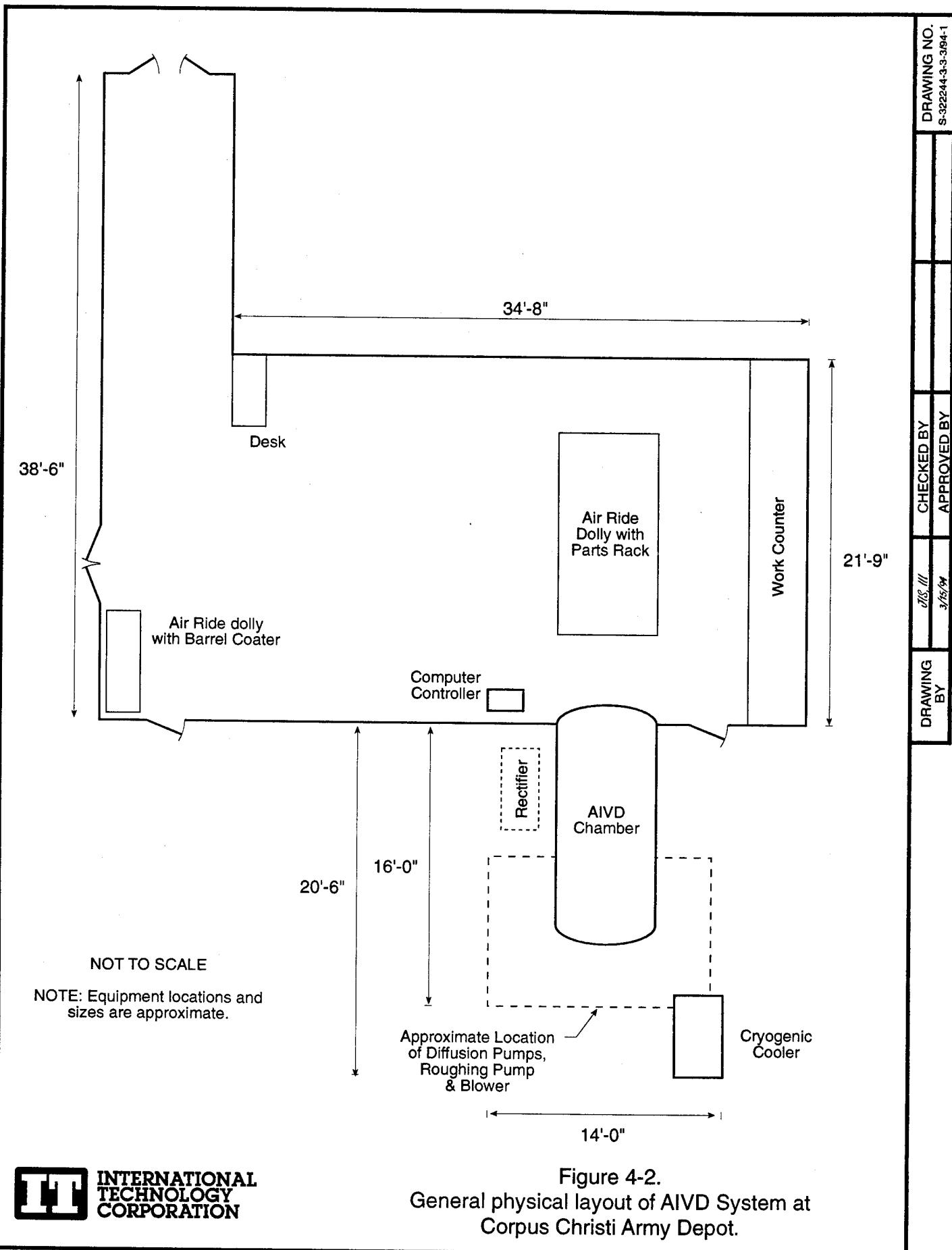


Figure 4-2.
General physical layout of AIVD System at
Corpus Christi Army Depot.

A substantial volume of cooling water is currently used by CCAD to operate the system. CCAD operators recommend that the use of a water chiller be investigated as a potential means to reduce the quantity of water required. This would also permit the use of conditioned water that would prevent buildup of calcium scale in the cooling system. Other recommendations included construction of a clean-room large enough to allow use of multiple parts racks and dollies, and inclusion of a pre-award survey at the vendors facility to ensure that the specific equipment to be installed is fully operational prior to shipment. The latter recommendation should help minimize startup times.

4.3 TOAD

TOAD supplies and maintains Army communications and electronic equipment. Approximately 40 percent of the current work load is overhaul and maintenance. New fabrication makes up the balance of the workload and is increasing. Application of cadmium surface coatings by electroplating is used during standard operations and wastes typical of cadmium plating are generated (Appendix C). Additionally, abrasive blasting and hand sanding generates residuals contaminated with cadmium. Because cadmium contamination is present in approximately 60 percent of the total hazardous waste generated by the depot (Appendix D), TOAD is seeking to replace at least part of its cadmium plating with aluminum AIVD. The type of parts that are currently plated with cadmium at TOAD and that are candidates for AIVD coatings are shown in the photographs included in Appendix E.

Initially, the AIVD system was to be acquired and installed in Bay 1 of Building 1B. However, plans were subsequently changed and acquisition of an AIVD system has been delayed for at least two years. The AIVD system, when acquired, will be installed in a new Industrial Operations building which is currently being designed.

5.0 Implementation of AIVD at TOAD

In general, the AIVD coating process is impacted by few regulatory restrictions and generates essentially no wastes. Cadmium electroplating is extensively regulated, due to its toxicity, and generates significant wastestreams. Cadmium is one of the most common contaminants found in industrial wastes generated by maintenance operations at Army depots. It is anticipated that the restrictions and costs associated with cadmium electroplating will continue to increase. The nature of the regulated wastes generated, RCRA Hazardous Wastes, includes potential future liabilities if problems arise with the method of ultimate disposal. Conversely, it is anticipated that the relative costs of AIVD coatings will decrease as the technology continues to advance and mature. Wider application and usage also will likely lead to cost saving developments. Based on these general findings and on specific successes achieved by ANAD, CCAD, and other military and commercial applications, TOAD Production Engineering staff have determined that AIVD would benefit their operations. The USAEC provided technical assistance to facilitate implementation of this technology. Review of the capital equipment acquisition process revealed the need for preparation of formal Bid Specifications, an Economic Analysis, and a Work Order. A summary of these efforts and the work products provided to TOAD is presented below. Copies of the referenced documents are included in this report as Appendices as noted.

5.1 Bid Specifications

An equipment Bid Specification was prepared for implementation of AIVD at TOAD. The specification, presented in Appendix F, was prepared in the format specified by the TOAD Production Engineering staff. Information acquired during the project from TOAD, ANAD, CCAD, and equipment vendors was used in preparing this document. Because a significant time will lapse prior to procurement of an AIVD system, the Bid Specification will have to be reviewed and updated/revised as necessary to reflect current conditions at the depot and any advances in AIVD technology.

The Bid Specification is intended to identify the minimum requirements for the design, manufacture, inspection, performance, and installation of an AIVD system. The specification sets minimum criteria so that technological advances are not limited. A full size chamber, 6 by 12 feet, is specified. Although smaller chambers are available and the possibility of specifying a smaller vacuum chamber was discussed with the Production Engineer, a full size system has greater flexibility in operation and throughput. Based on lessons learned at ANAD and CCAD, a cryogenic pump ("cryopump") and a computer controller are included in the Bid Specification as requirements. Standard features including air ride dollies, parts racks, and dual barrel coaters are also included. In addition to the equipment, the specifications also address provisions for technical manuals and training of operators.

5.2 Economic Analysis

A draft Economic Analysis (EA) based on data and information currently available was prepared for implementation of AIVD at TOAD. Critical information, including current and projected work loads, number of parts that will be plated with the substitute coating, and waste generation rates for specific cadmium plating operations was either not available or is anticipated to change prior to implementation. The draft EA, prepared in format specified by TOAD, will serve as a guide for subsequent revision when the anticipated procurement is imminent.

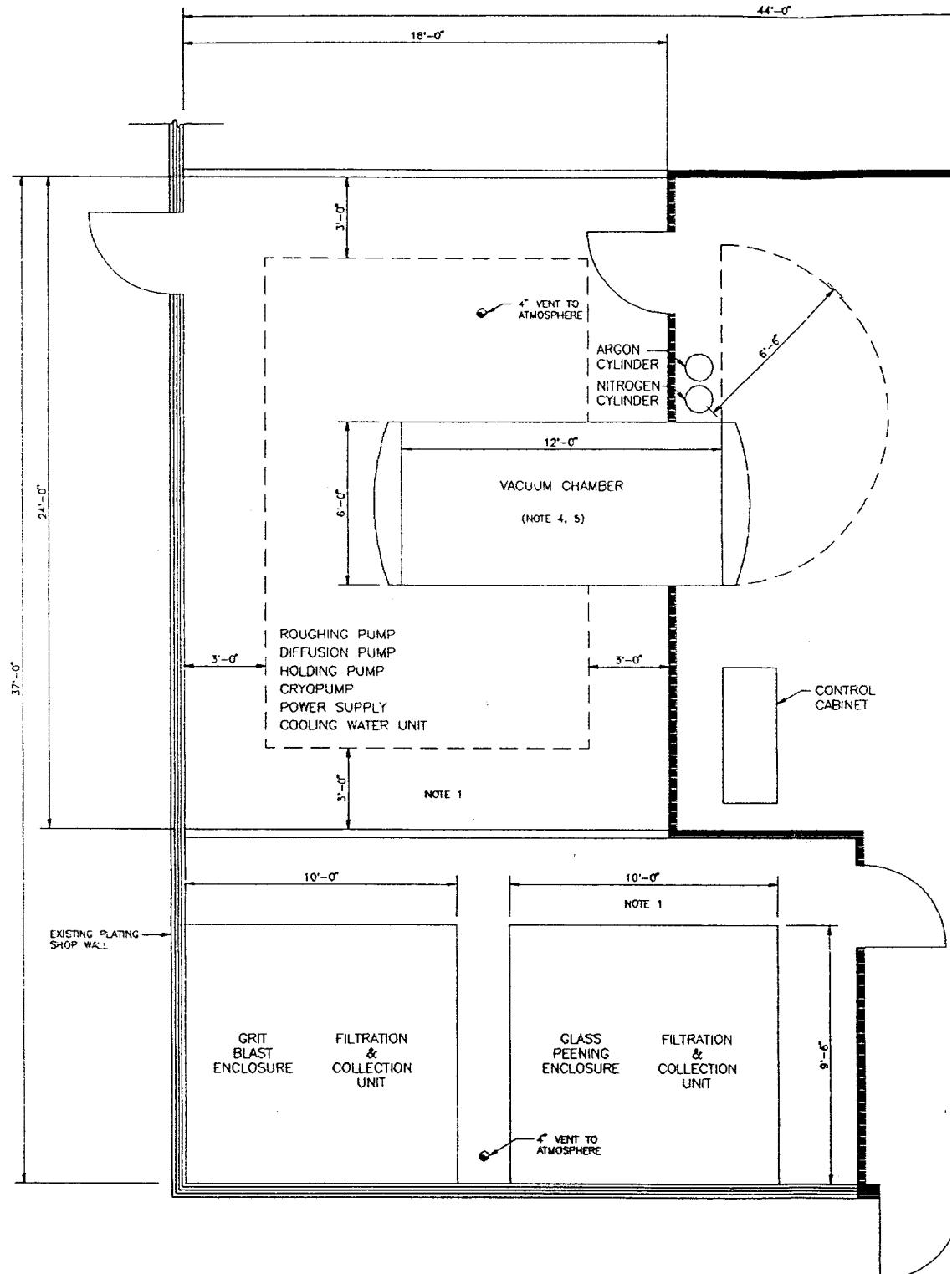
Several significant assumptions were required for completion of the draft EA which is presented in Appendix G. Most significantly, the approximate number of parts that would receive the AIVD coating was estimated as a percentage (i.e., 80 percent) of the cadmium plated workload. This assumption controls the number of shifts that an AIVD system would operate, which in turn controls labor and utility costs. Similarly, the actual reduction in cadmium waste generation rates had to be estimated. Based on the assumptions made in the EA, implementation of AIVD at TOAD can achieve cost savings when compared, over the life of the system, to conventional cadmium electroplating. These and other assumptions, made with the input of the Production Engineering staff at TOAD, must be reviewed and revised as appropriate to accurately reflect current and projected conditions at the time that acquisition of the capital equipment is pursued.

5.3 Work Order

A Work Order was prepared for completion of site preparation work necessary for installation of an AIVD system at TOAD (Appendix H). This Work Order was prepared to facilitate reviews and planning that will be conducted by the facility engineers. Originally, TOAD production engineers planned to install the AIVD unit in Bay 1 of Building 1B. Since that time, however, it has been determined that the AIVD system will be located in the new Industrial Operations building. Procurement of the AIVD system will be scheduled in concert with completion of this facility. The information included in the draft Work Order is intended to provide information on required space, utilities, floor loadings, etc., that will be used by the designers of the new building in planning for an AIVD system.

The Work Order specifies the requirements for a "clean room", approximately 26 by 37 feet, to serve as the air conditioned AIVD plating shop. This room must have smooth (no cracks or grooves), level (to 1/4 inch in 5 feet or better) floors. Epoxy floor coating is recommended. The floor loading limit must be 1000 pounds per square foot, or greater. The air conditioning must be capable of maintaining $70^{\circ}\text{ F} \pm 2^{\circ}$ at a relative humidity of 50 percent \pm 5 percent. A single 4-inch-diameter PVC exhaust duct will vent the vacuum pump through a roof ventilator. This is the only air discharge. Non-contact cooling water (40 psig, $<80^{\circ}\text{F}$, 24 gpm) will be required for the pumps. Other utilities include electrical (480 V, 3 Phase, 60 Hz, 300 amp for the AIVD system and 460 V, 3 Phase, 60 Hz, 3 amp and 110 V, 1 Phase, 60 Hz, 6 amp for the blast booths), air (60-80 psig, 70 cfm for the blast booths and parts rack dollies), and welding quality compressed argon and nitrogen gas.

An area of approximately 44 by 37 feet will be required for the AIVD system, including the clean room, all mechanicals, and pre- and post-treatment blast enclosures. A diagram of the proposed floor plan is shown in Figure 5-1.



FLOOR PLAN
SCALE: 3/8'=1'-0"

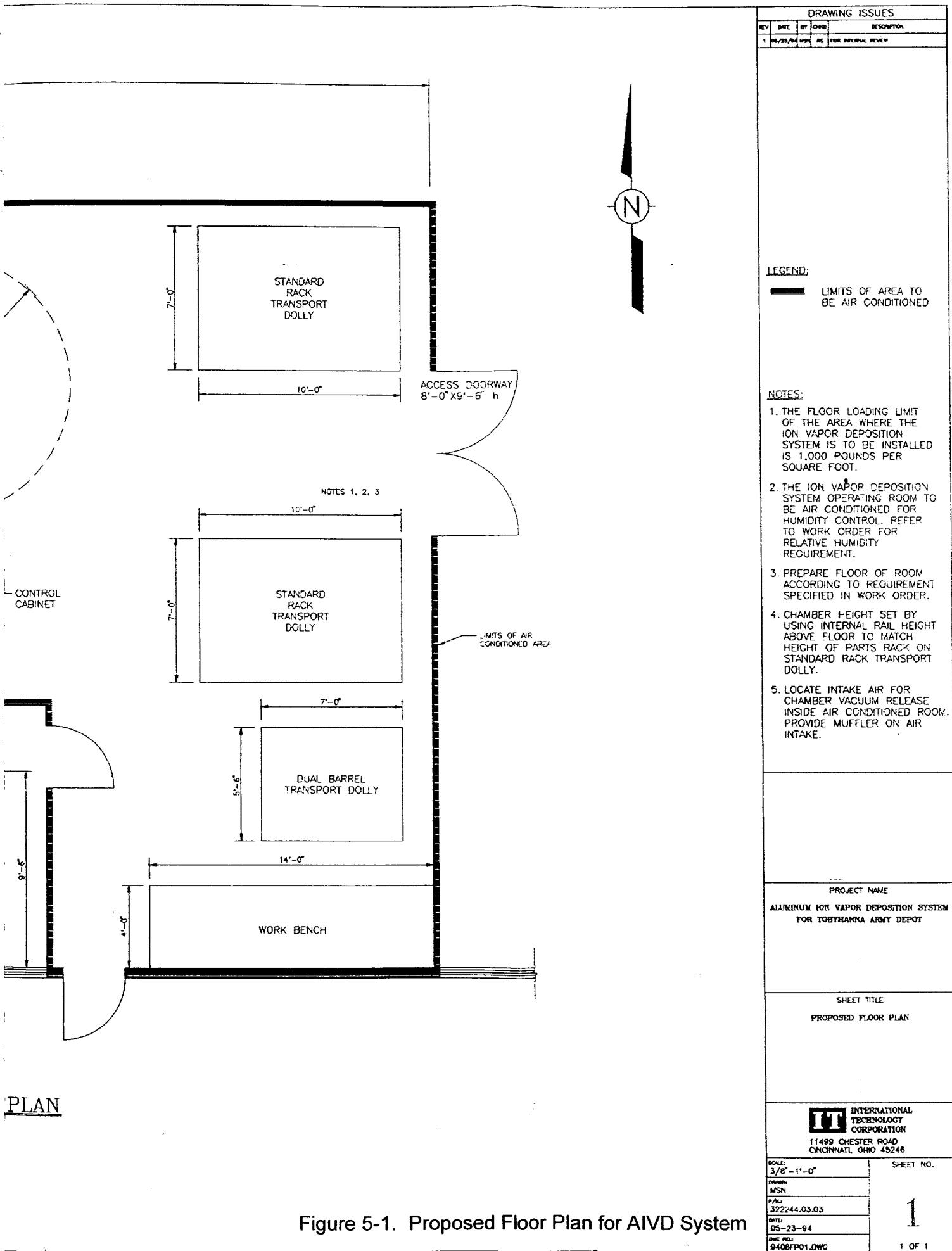


Figure 5-1. Proposed Floor Plan for AlVD System

5.4 Substitution of Coatings

The substitution of aluminum coatings for cadmium coatings is controlled by the weapons or systems program office responsible for the part. Each part must be evaluated by the program office to determine if the substitute coating is acceptable. The qualification testing and acceptance process can be a time consuming undertaking.⁸ "Blanket approvals" are not typical and the approval process is carried out separately for each specific part. To provide guidance for this process, a decision tree or logic chart can be developed. An example of such an AIVD candidate part flow chart is provided in Figure 5-2. This chart was adapted from one developed by CCAD that was used in gaining acceptance of AIVD coatings. A specific logic chart should be developed at each location (i.e., depot) and potentially for each weapon system or parts program office/manager during implementation of AIVD coatings. The chart should be developed with input from the production engineering group, the plating shop, and the program manager responsible for the part or system. Print and assembly drawings of the part and the weapon system must be reviewed during the assessment to acquire information on tolerances and critical coatings, etc.

5.5 Recommendations

At this time, it is anticipated that acquisition of an AIVD system and implementation of this plating technology at TOAD will occur within the next several years, however, the specific timing has not been defined. The procurement schedule will be determined by the construction schedule for the new industrial operations building (where the AIVD system will be located) and allocation and prioritization of future capital equipment acquisition funds. As the new industrial operations facility is completed and funding becomes available, the Bid Specification, Economic Analysis, and Work Order for the AIVD system (Appendices F, G, and H) should be reviewed, revised, and updated as necessary to reflect conditions that exist at that time. In particular, the number and types of parts plated may change significantly over time. The work load may have changed, for example, due to modifications to the depot's mission, privatization of work, or import of work from other depots that are impacted by base closure or realignment. Additionally, the unit costs associated with management and disposal of cadmium contaminated wastes may have increased.

The depot may also experience increases in labor and utility costs or may implement waste minimization activities that reduce waste generation rates. Any of these, or other, changes from the conditions assumed in this document, must be taken into account by updating the assumptions and cost components used and the return on investment calculated in the Economic Analysis. Additionally, the state-of-the-art of AIVD plating technology should also be reviewed. This can be accomplished through contacts with other military and commercial users and equipment vendors. The focus of this review should be to ensure that any technological advances are considered during the procurement process and incorporated as appropriate in the system acquired by TOAD. The Bid Specification and Work Orders should be reviewed and revised to ensure that the system acquired by the depot incorporates the benefits of any advances in AIVD technology or the technology associated with ancillary equipment and processes. In addition to updating the Bid Specification, Economic Analysis, and Work Order, the potentially time consuming processes of obtaining authorization for the substitute coating should be initiated early in the implementation process.

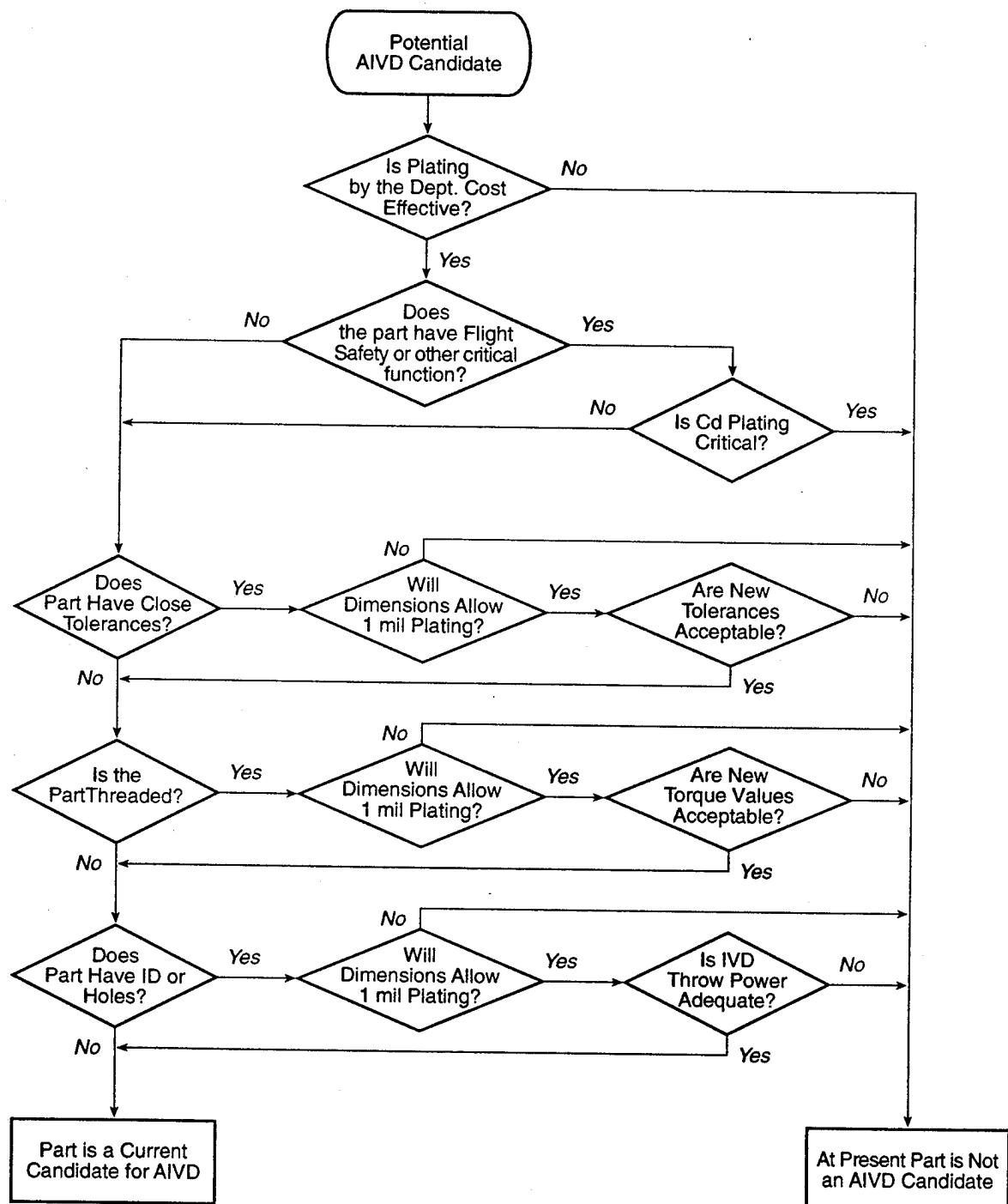


Figure 5-2.
Example AIVD Candidate Flow Chart
Developed by CCAD.

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Appendix A

Trip Report: ANAD

**Minutes of Site Visit
for Hazardous Waste Minimization Technology Transfer/Implementation
Support for Depot System Command Installations**

USAEC Contract No. DACA31-91-D-0074
Task Order No. 6
IT JTN 322244

March 8, 1994
Anniston Army Depot
Anniston, AL

Prepared by:

IT Corporation
Cincinnati, Ohio

A site visit for the referenced Task Order was held on March 8, 1994 at the Anniston Army Depot (ANAD), Anniston, Alabama. The purpose of the site visit was to observe operation of the Aluminum Ion Vapor Deposition (AIVD) systems in use at the facility and to discuss procurement, installation and operation of the AIVD system at ANAD to facilitate procurement of a similar system at Tobyhanna Army Depot (TOAD). The following personnel participated in the meeting:

Anniston Army Depot (ANAD)

Joe Crews	205/ 235-4187
Charles Speers	

Tobyhanna Army Depot (TOAD)

Pat Tierney - Production Engineering Division	717/ 894-6724
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IT Corporation

Bob Hoye - Project Manager	513/ 782-4776
Rajib Sinha - Project Engineer	513/ 782-4694

A summary of the major issues discussed is presented below.

AIVD System Description and Operation

- ANAD has two AIVD systems in operation. Both systems were supplied and installed by Abar Ipsen Industries, Bensalem, PA.

- Pretreatment for parts prior to coating in the AIVD system typically includes vapor degreasing, removal of existing cadmium or aluminum coating in stripping tanks, and blasting with aluminum oxide in a blast booth. The blast booths used for cleaning parts that will be coated in the AIVD system are dedicated and segregated for this purpose only and are not used for parts that will be coated by other means.
- The system consists of the AIVD chamber, a mechanical "rough" pump, a diffusion pump, and a cryogenic cooler. The first system was not originally supplied with a cryogenic cooler. In the past, pump down time for that system averaged one hour or more. Addition of the cryogenic cooler has reduced pump down time to about 30 minutes. Both AIVD systems are now equipped with cryogenic coolers. Similarly, a diffusion pump is required to minimize pump down time and is essential for system operation.
- Parts to be plated are hung from a parts rack. Air flotation transport dollies are used to handle the parts rack. Once a loaded rack is placed in the AIVD chamber, the door is closed and the coating cycle started. ANAD also uses a barrel coater for small parts.
- The system is operated manually from a control panel located near the AIVD chamber. As the first step, the AIVD chamber is evacuated to a pressure of approximately 10^{-6} torr using the mechanical and diffuser pumps. Argon is then pumped into the chamber and a high electrical current generates a plasma within the chamber. This plasma provides a final cleansing of the parts. The argon plasma cleaning cycle is approximately 16 minutes in duration.
- The system contains seven ceramic boats where the aluminum wire is melted. Each boat can be turned on or off individually. The boats are electrically heated to a temperature of approximately 2000°F and aluminum wire is fed to the boats. When all boats are on-line, the boat rack drive is started and it moves the boats down the length of the AIVD chamber. The speed of the boat rack drive and the rate of aluminum wire feed is manually controlled at the control panel for each pass of the boat rack drive. The boat rack drive stops at the end of each pass and must be manually restarted for additional passes. The number of passes required depends on the thickness of coating desired.
- At the end of the coating cycle, a ten minute cool down period is allowed. The AIVD chamber is then brought back to atmospheric pressure and the door opened. The parts rack is transferred to the air ride dolly and removed from the chamber.
- Aluminum coated parts are then peened with glass beads in one of the dedicated blast booths. This process densifies the coating, removes imperfections in the coating and

reduces coating porosity. The parts then receive a conventional chromate conversion coating. This is an important step for the parts processed at ANAD.

AIVD Room

- The attached figure shows the general layout of the AIVD room at ANAD. This figure shows only the relative locations of the various equipment and is not to scale.
- The front end of the AIVD chamber is located in an air conditioned room which helps reduce the humidity of the air (and therefore reduce pump down time) and minimizes airborne contaminants. ANAD has experienced some contamination problems due to inadequate ventilation at its plating shop. The suction line for air introduced into the chamber at the end of the plating cycle is also located within this air conditioned room to minimize this problem.
- The parts rack is loaded into the AIVD system with the help of an air ride dolly which has flat feet that ride on a cushion of air. The floor for this room consists of steel plates and is covered with a durable epoxy coating. This allows the dolly to ride smoothly without binding. Also, joists were used in the basement to add strength to the floor.

Miscellaneous

- ANAD uses one cylinder of argon approximately every two months.
- The aluminum shields in the AIVD chamber become coated with aluminum over time and require cleaning. The porous aluminum deposits, if allowed to remain, trap moisture and increase pump down time. ANAD cleans the aluminum shields in their systems approximately once every two months or less. The shields are removed and cleaned by dipping in a caustic (NaOH) strip tank.
- Abar Ipsen provided two weeks of onsite training for ANAD personnel. Five operators were trained in the operation of the AIVD system.
- Approximately six months of testing and evaluation were required to define system parameters and operation that produces the desired coating thickness on the parts.
- The AIVD system vents to the atmosphere through a 6"Ø PVC vent.

Potential changes for a new AIVD system

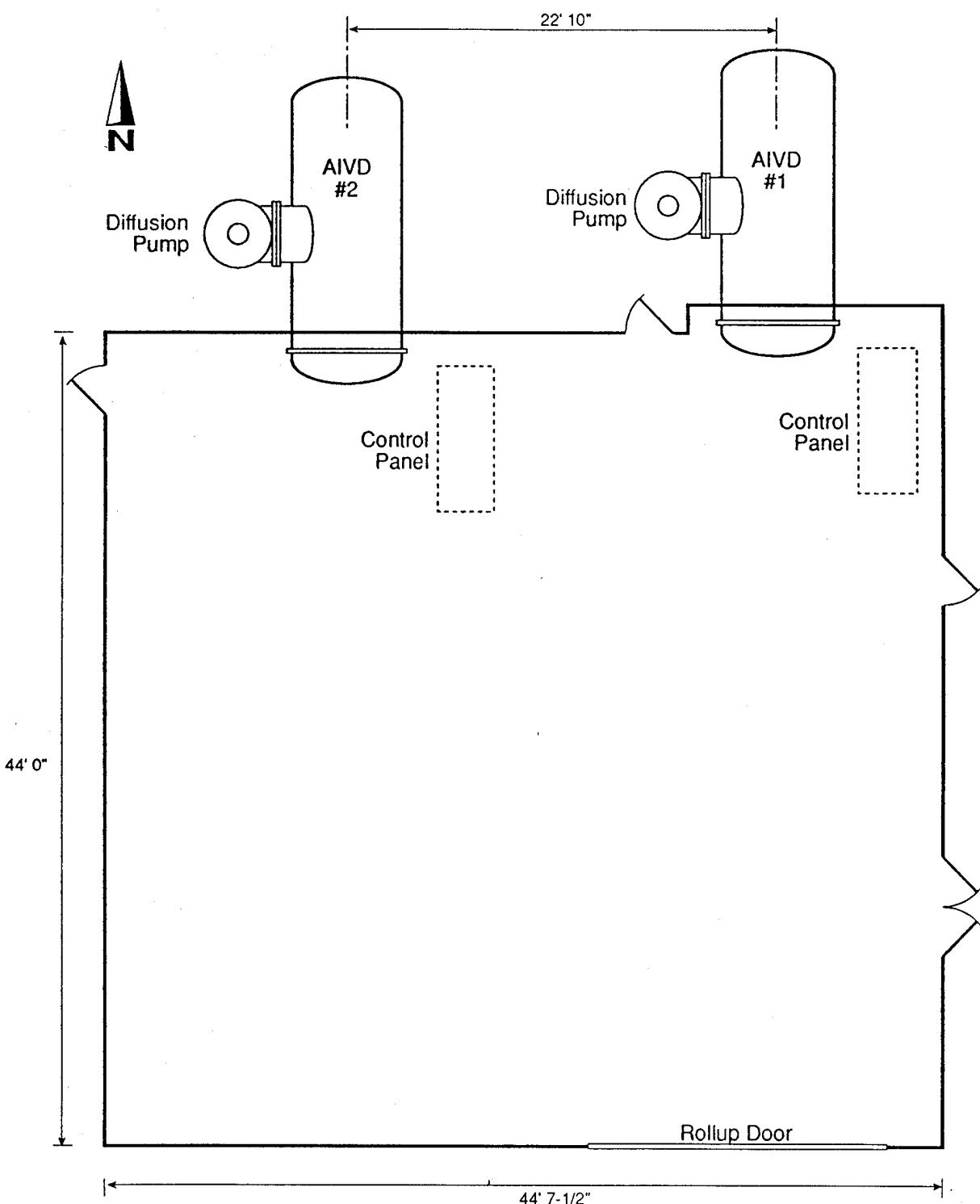
- Computer controls on the system would simplify operation.

LIST OF DOCUMENTS OBTAINED FROM ANAD

1. Memorandum for C,MQAD - Ion Vapor Deposited Aluminum, May 15, 1991
2. ANAD Economic Analysis for Aluminum Ion Vapor Deposition Unit, July 2, 1991
3. Contract Documents, September 25, 1991
4. Drawings for AIVD System at ANAD

DRAWING NO.
S-322244-3-394-1

DRAWING BY
JRC/M
J/22/84
CHECKED BY
APPROVED BY



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NOT TO SCALE

NOTE: Equipment locations and sizes are approximate.

General Physical Layout of
AIVD Systems at ANAD.

Appendix B

Trip Report: CCAD

REVISED
Minutes of Site Visit
for Hazardous Waste Minimization Technology Transfer/Implementation
Support for Depot System Command Installations

**USAEC Contract No. DACA31-91-D-0074
Task Order No. 6
IT JTN 322244**

March 2, 1994
Corpus Christi Army Depot
Corpus Christi, TX

Prepared by:

IT Corporation
Cincinnati, Ohio

A site visit for the referenced Task Order was held on March 2, 1994 at the Corpus Christi Army Depot (CCAD), Corpus Christi, Texas. The purpose of the site visit was to observe operation of the Aluminum Ion Vapor Deposition (AIVD) system in use at the facility and to discuss procurement, installation and operation of the AIVD system at CCAD to facilitate procurement of a similar system at Tobyhanna Army Depot (TOAD). The following personnel participated in the meeting:

U.S. Army Environmental Center (AEC)

Dick Eichholtz - COTR 410/671-1565

Corpus Christi Army Depot (CCAD)

Jim Holiday 512/ 939-2603
Ralph Boughton 512/ 939-4629

IT Corporation

Bob Hoye - Project Manager 513/782-4776
Rajib Sinha - Project Engineer 513/782-4694

A summary of the major issues discussed is presented below.

AIVD System Description and Operation

- CCAD installed the AIVD system in January 1993. The system was supplied and installed by IVI Corporation, Pembroke, Massachusetts. System operation is fully automated and controlled by a computer.

- Pretreatment for parts prior to coating in the AIVD system typically includes degreasing, removal of existing cadmium or aluminum coating in stripping tanks, and blasting with aluminum oxide in a blast booth.
- The system consists of the AIVD chamber, a mechanical "rough" pump, a blower, two diffusion pumps, and a cryogenic cooler. The AIVD chamber is a 6' diameter by 12' long vacuum vessel in which metal parts are coated with aluminum under extremely low pressure in an inert atmosphere. The pumps and the blower are used to evacuate the AIVD chamber to a high vacuum, while the cryogenic cooler is used to remove moisture from within the chamber to facilitate creation of the vacuum. Removal of moisture significantly reduces pump down time.
- Parts to be plated are hung on eye bolts fixed on a parts rack (the eye bolts are a modification of the racking system). Air flotation transport dollies are used to handle the parts rack. Once a loaded parts rack is placed in the AIVD chamber, the door vacuum chamber is closed and the coating cycle started. Other methods of handling parts include the use of a barrel coater for small parts and a rotary parts rack for long parts, such as pipes.
- The computer controller is programmed at the start of the cycle to control all operational parameters, including, the argon cleaning cycle, the number of passes of the boats, the time per pass, the aluminum wire feed rate.
- The AIVD chamber is evacuated to a pressure of approximately 10^{-6} torr using the mechanical pump, blower and diffuser pumps. Argon is then pumped into the chamber and a high electrical current generates a plasma within the chamber. The argon ions bombardment provides a final cleansing of the parts.
- The ceramic boats are electrically heated to a temperature of approximately 2000°F and aluminum wire is fed to the boats. When all boats are on-line, the boat rack drive moves the boats the length of the chamber and back.
- At the end of the coating cycle, a ten minute cool down period is allowed. The AIVD chamber is then brought back to atmospheric pressure and the door opened. The parts rack is transferred to the air ride dolly and removed from the chamber.
- The aluminum coated parts are then peened with glass beads. This process densifies the coating, removes imperfections in the coating and reduces coating porosity. A chromate conversion coating is then typically applied to the parts.
- The computer controller permits an auto startup sequence which initiates system warm up prior to operating personnel arriving on site. This reduces the initial startup time for each days operation.

AIVD Room

- The attached figure shows the general layout of the AIVD room at CCAD. This figure shows only the relative locations of the various equipment and is not to scale.
- Pump down time for the AIVD system is dependent on the humidity of the air in the system. Therefore, the front end of the chamber is located in an air conditioned room which helps reduce the humidity of the air and minimizes airborne contamination. The suction line for air introduced into the chamber at the end of the plating cycle is also located within this room.
- The air ride dolly used to load the parts rack into the AIVD system has flat feet that ride on a cushion of compressed air. The floor was smoothed to eliminate cracks or holes and then covered with an epoxy coating. This allows the dolly to ride smoothly without binding. The coating used at CCAD is the same as that used at ANAD.
- The "clean" room dimensions at CCAD are approximately 34'-8" wide by 21'-9" long. The AIVD system is located off-center in the shorter wall. The system extends approximately 20'-6" behind this wall, including the cryogenic unit.

Utilities

- Power - 480V, 3Ø, 60 Hz, 250 amps
- Water - City water is provided for non-contact cooling of the pumps and the boats. 1-1/2" piping is used for this connection. The water is used once and discharged without recirculation.
- Compressed air - Shop air at a minimum of 80 psig is required to operate the vent valves (roughing valve, foreline valves, and high vacuum valve) and for the air ride dolly.

Spare Parts

- The aluminum wire used for coating is obtainable from the manufacturer or other sources.
- Replacement boats are obtained from the manufacturer. Each boat has an approximate life of 2,000 hours operation.

Miscellaneous

- System noise is less than 80 dB.

- Argon usage is low and CCAD anticipates one argon cylinder will last approximately one year at current production rates.
- The aluminum shields in the AIVD chamber become coated with aluminum over time and require cleaning. The porous aluminum deposits, if allowed to remain, trap moisture and increase pump down time. Each shield weighs approximately 25 lbs. They are periodically removed and cleaned by dipping in a caustic (NaOH) strip tank. Mr. Holiday recommends that the size of the shields be specified to ensure they fit into existing caustic dip tanks at TOAD. CCAD currently disposes the aluminum hydroxide sludge generated from this cleaning process as a hazardous waste due to the pH. The frequency of cleaning is dependent on production rates and is initiated whenever pump down time increases noticeably.
- CCAD plans to experiment with the use an india ink stamp on AIVD plated parts to permits AIVD coated parts to be differentiated from cadmium coated parts. This will facilitate the use of the appropriate stripping solution for removal of coats when the parts return from the field.

Costs

- The clean room construction required approximately \$50,000 at CCAD. A copy of the work order for the room may be available from CCAD but was not obtained during the visit.
- The AIVD system was approximately \$644,000. An additional \$10,000 to \$15,000 approximately was required for the automatic control system.
- Additional costs were incurred for installation, startup and training.

Permits

- Environmental permits were not required for the system. The vacuum pumps exhaust through the roof via a single 4"Ø PVC stack.

Potential changes for a new AIVD system

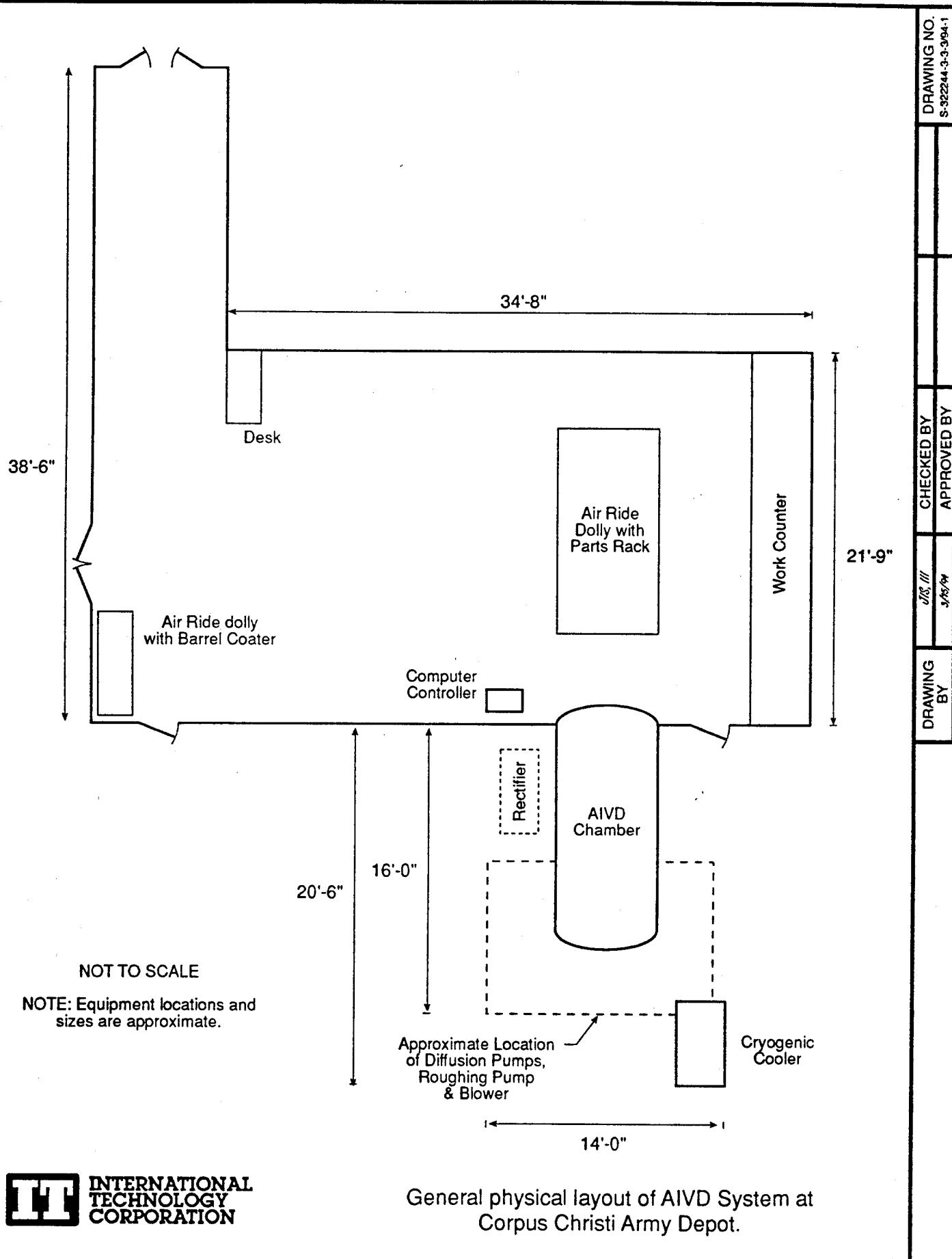
The following recommendations were offered by Mr. Holiday and Mr. Boughton:

- Training for operators in the use of the AIVD system should be scheduled to provide for one week of training, followed by one month of production use, followed by an additional week of training.

- An Intel 486 based computer for the control system would be beneficial for processing speed and ease of availability of spare parts. Ancillary equipment should include a color monitor and a 24-pin narrow carriage printer.
- CCAD does not use the rotisserie rack for coating barrels or pipes. Mr. Holiday recommends that TOAD evaluate it's parts to determine if such a rack would be required.
- A preaward survey at the vendors facility should be performed to ensure the equipment to be provided is operational.
- CCAD has added fixed eyebolts to the parts rack to permit centering of the parts in the openings provided for hanging parts. This reduces the occurrence of shorts and speeds operation. The parts rack should be specified to include these eyebolts.
- A substantial quantity of water is currently used by CCAD to operate the system. The use of a water chiller should be investigated as a potential means to reduce the quantity of water required. This would also permit the use of conditioned water to prevent calcium scale buildup in the cooling system.
- The "clean" room should be larger than the one they have to facilitate the use of multiple racks to allow higher production rates. Alternately, the chamber could be centered in the room to permit the use of two racks.

LIST OF DOCUMENTS OBTAINED FROM CCAD

1. Proposal drawing from Abar Ipsen showing layout of Ivadizer System
2. Memorandum - New Procedures for Processing Economic Analysis (EA) Documentation, January 5, 1994
3. CCAD Economic Analysis for Ion Vapor Deposition of Aluminum, March 21, 1990
4. Contract Documents and Bid Specifications, December 13, 1991
5. Memorandum - Utilities requirements for the Ion Vapor Deposition Equipment, November 16, 1992
6. CCAD Process Standard No.I.09 - Ion Vapor Deposition of Aluminum, June 24, 1993

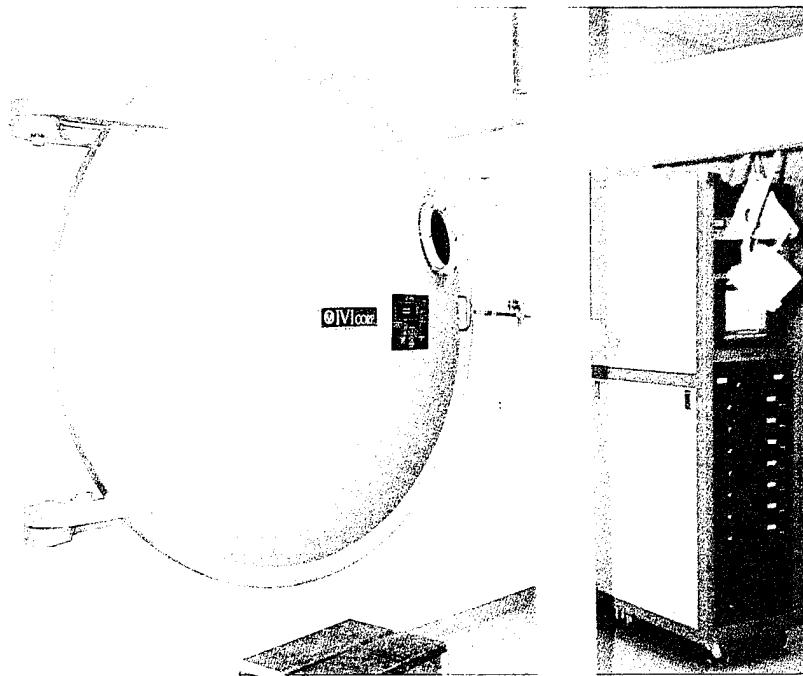


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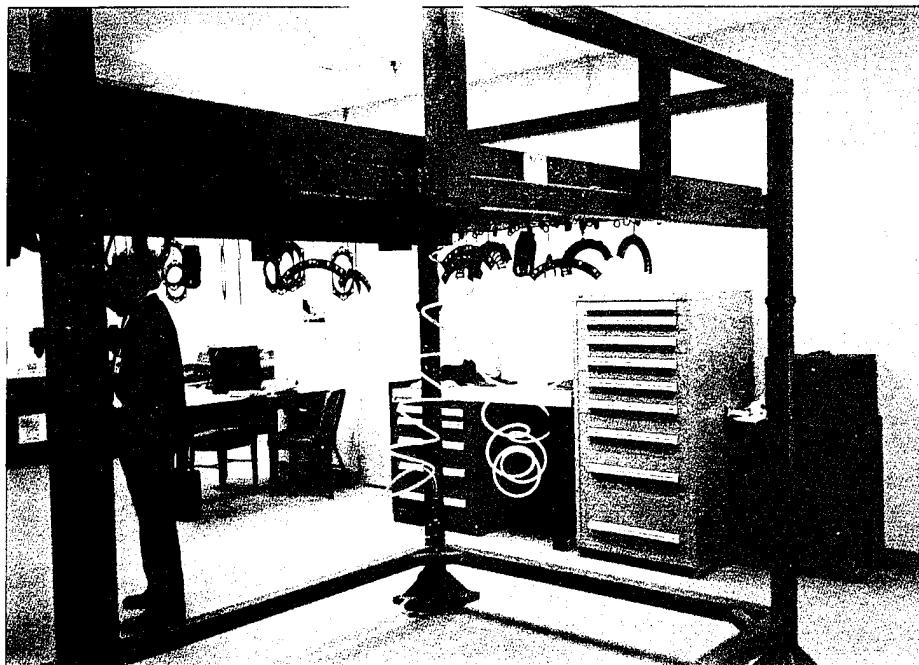
ADDENDUM TO SITE VISIT MINUTES:
SITE VISIT TO CORPUS CHRISTI ARMY DEPOT

IT Corporation
USAEC Contract No. DACA31-91-D-0074
Task Order No. 6
IT JTN 322244

PHOTOGRAPHS OF CCAD AIVD FACILITY
(Photographs taken on March 2, 1994)



Front end of the AIVD chamber located in the air conditioned room.

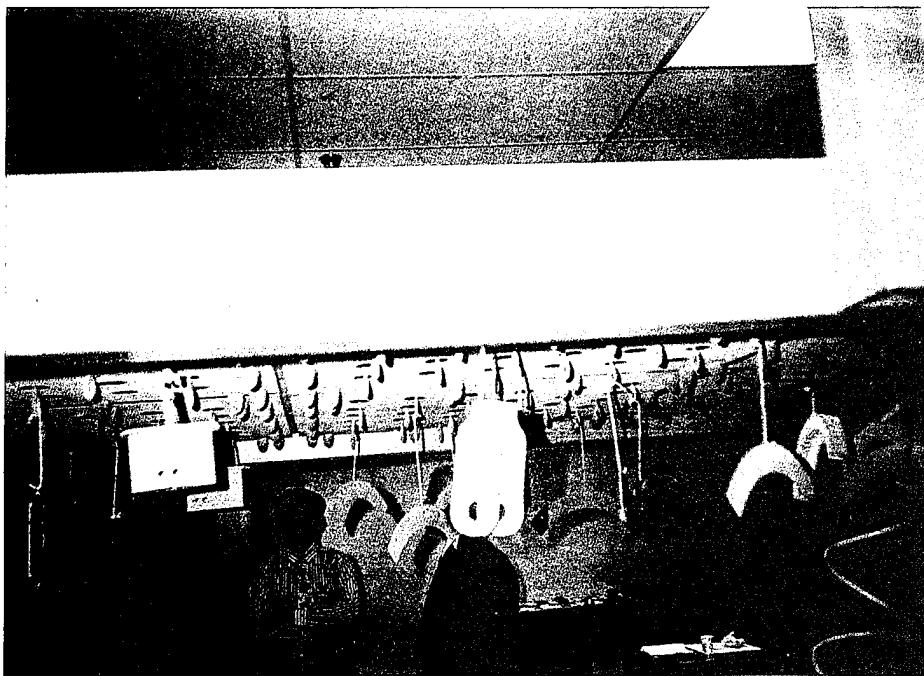


Air-ride dolly with parts rack. Note the compressed air connection and the flat feet.

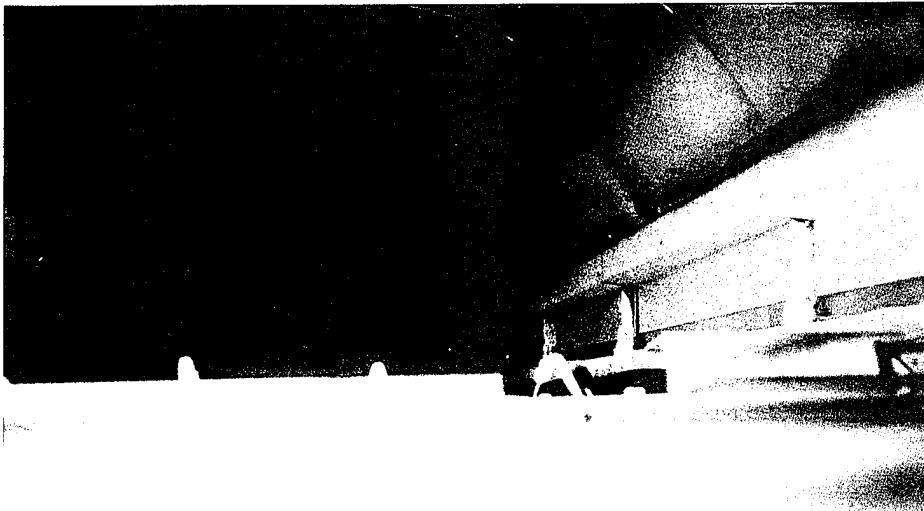


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Close-up view of the parts rack. Note the eye hooks used for hanging the parts.

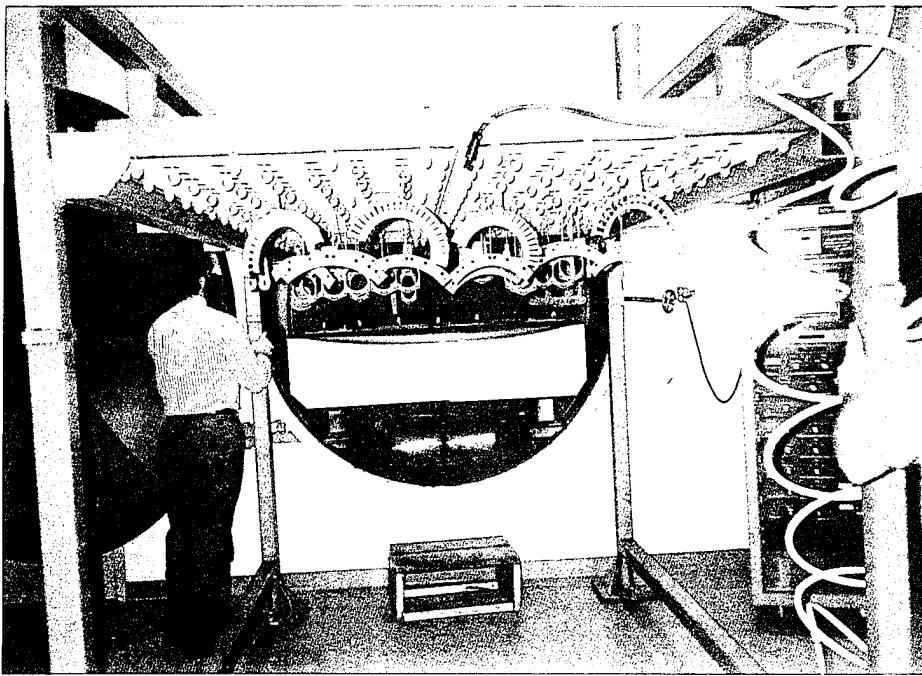


Inside the AIVD chamber. The boat rack drive is in the foreground. The tubes at the rear are part of the cryogenic cooling coils.

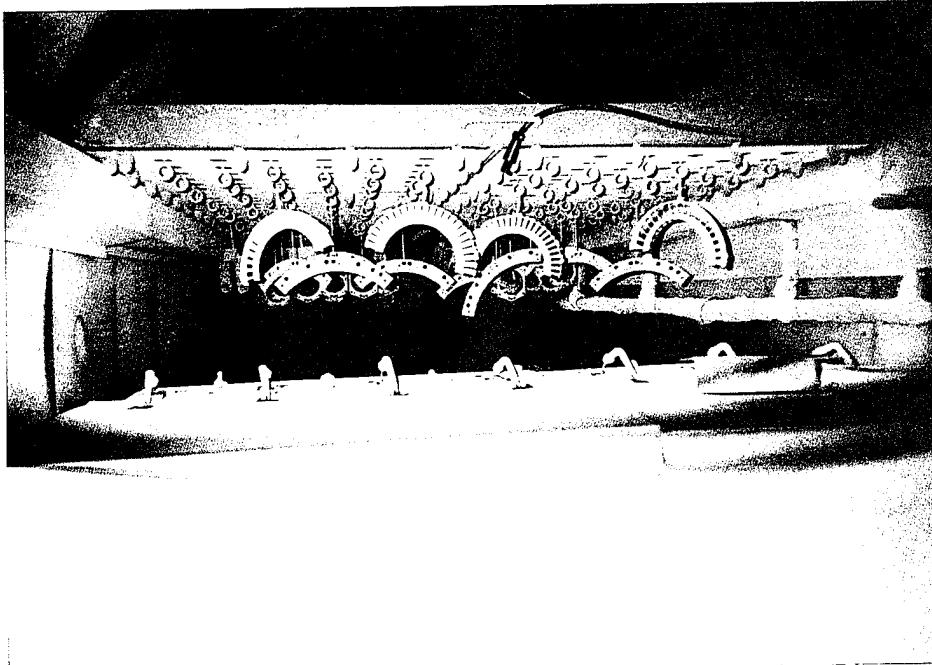
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Aligning the air-ride dolly and the loaded parts rack for placing in the AIVD chamber.

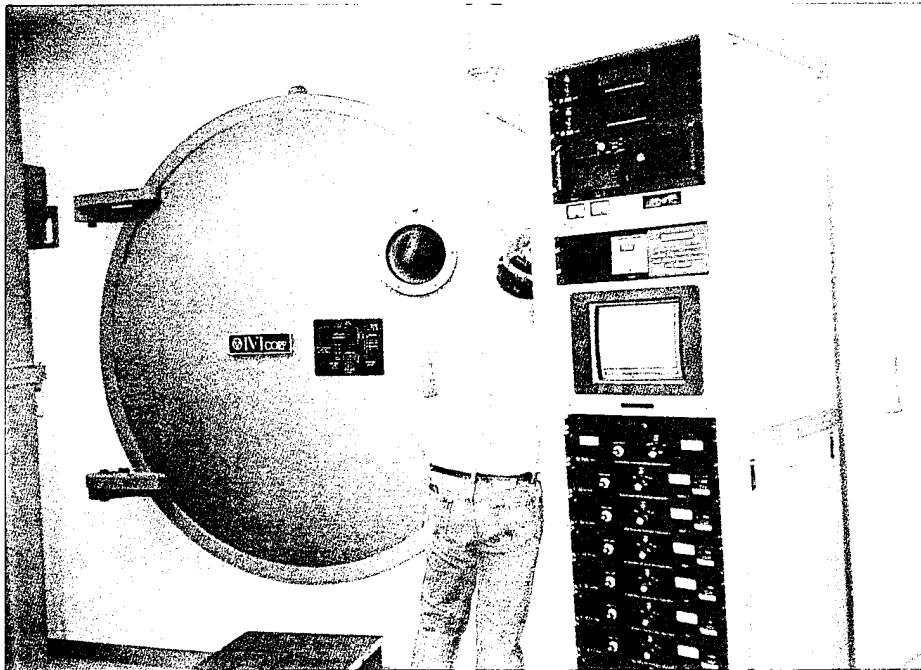


Loaded parts rack placed in AIVD chamber. The boats and aluminum wire feed are in the foreground.

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Closing the AIVD chamber prior to start of the coating cycle.
The computer controller is in the foreground.

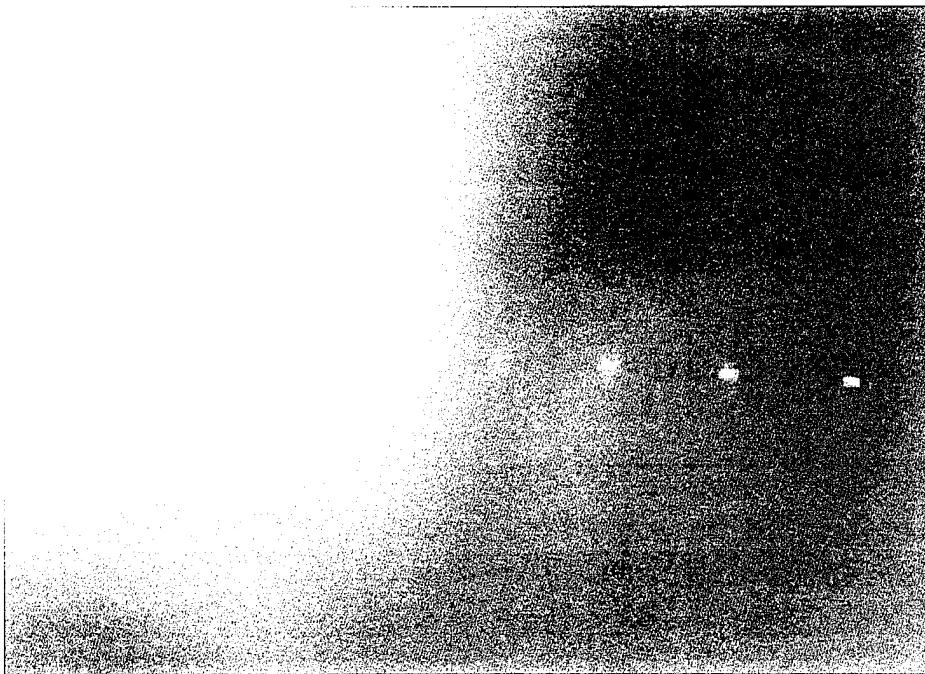


Programming the computer controller for the start of the
coating cycle.

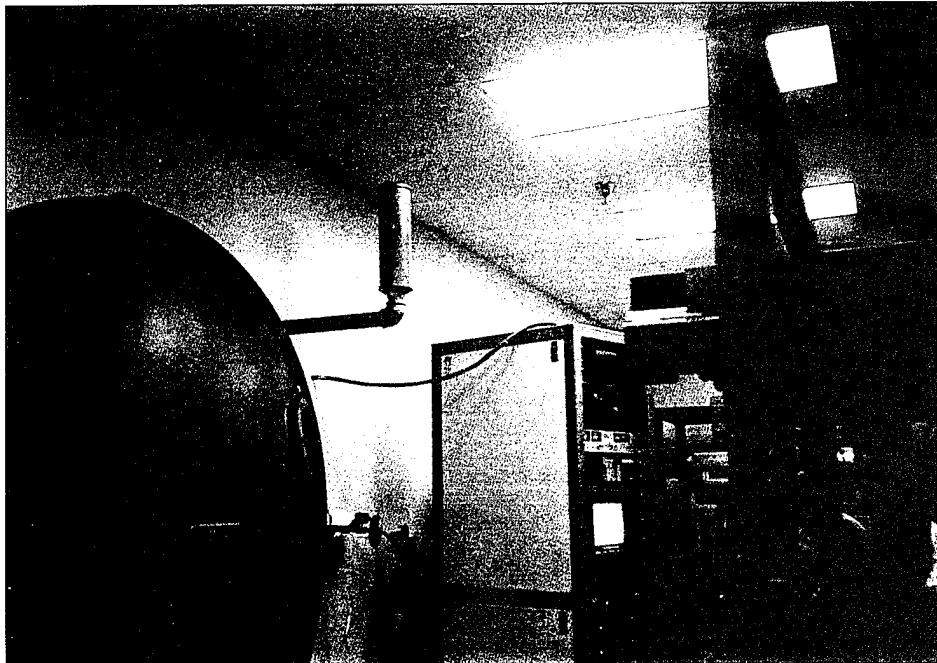
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Glow of the ceramic boats during coating.

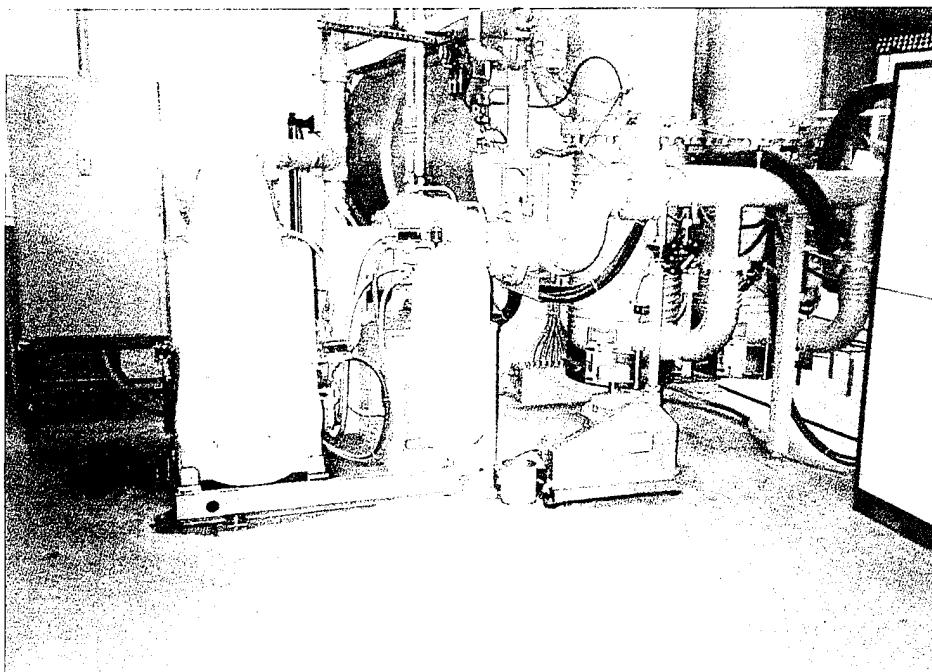


Front end of the AIVD system showing the suction line for air used to return the chamber to atmospheric pressure. The argon tank used for the plasma cleaning can be seen behind the computer controller.

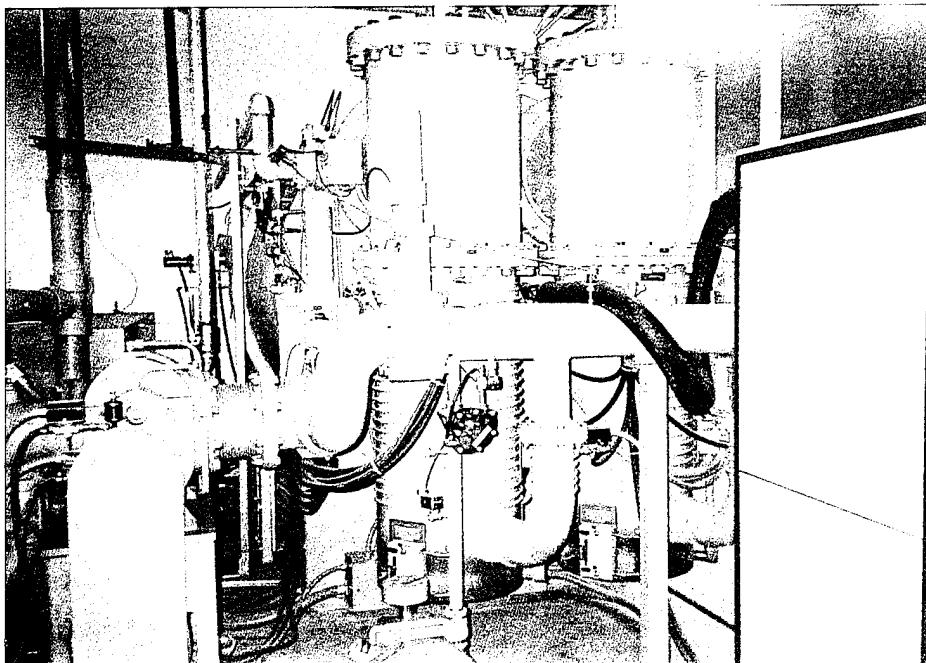


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Mechanical "roughing" pump and blower.



Diffusion pumps

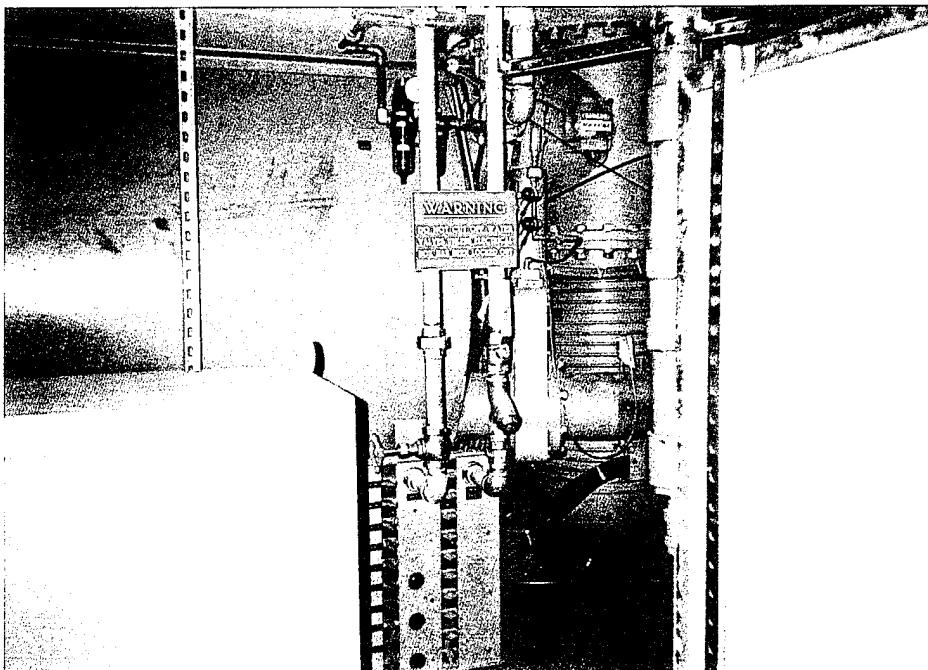
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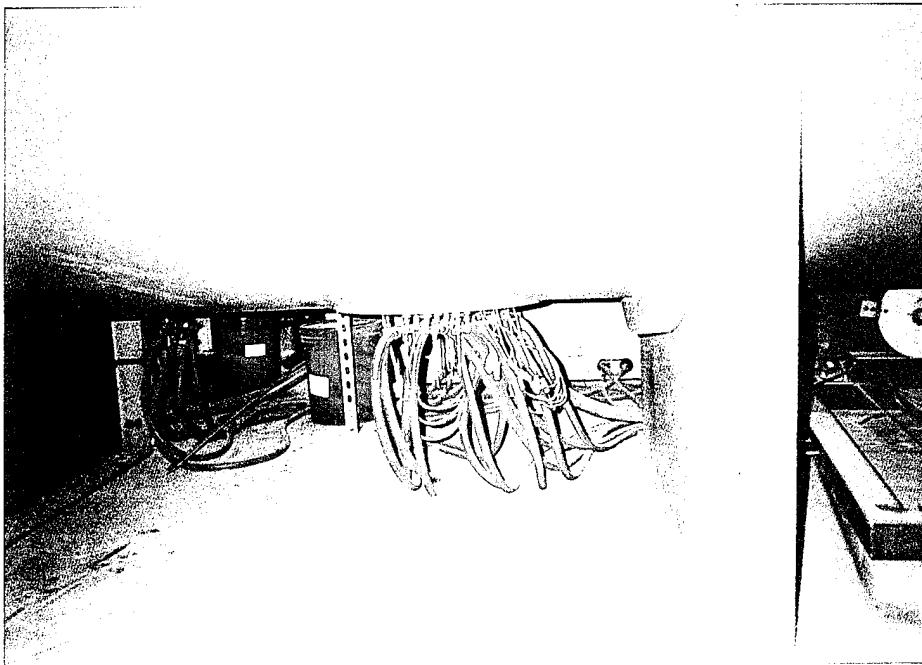
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Water supply manifold.

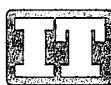


Water hoses entering AIVD chamber for cooling ceramic boats.

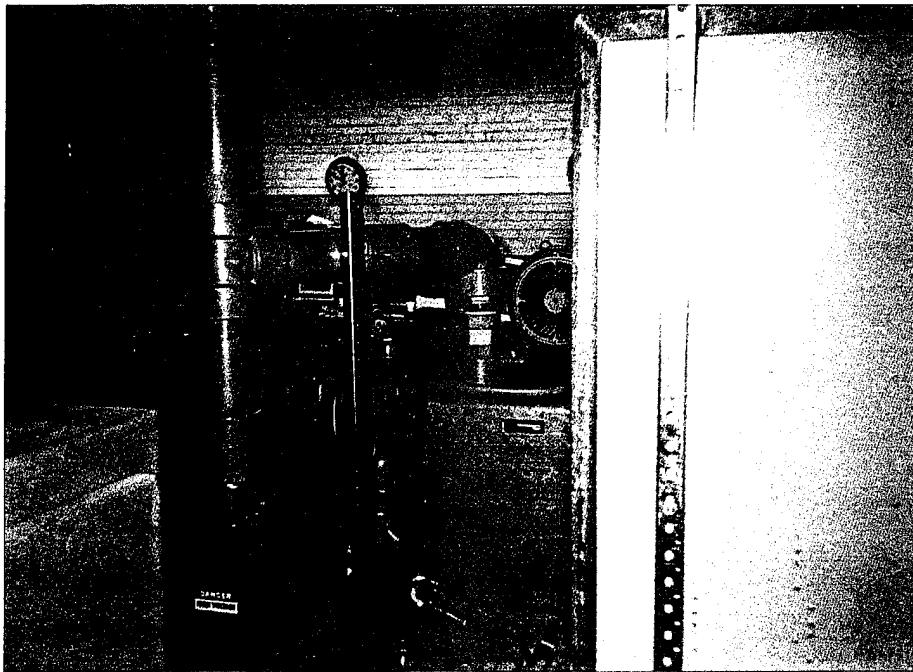
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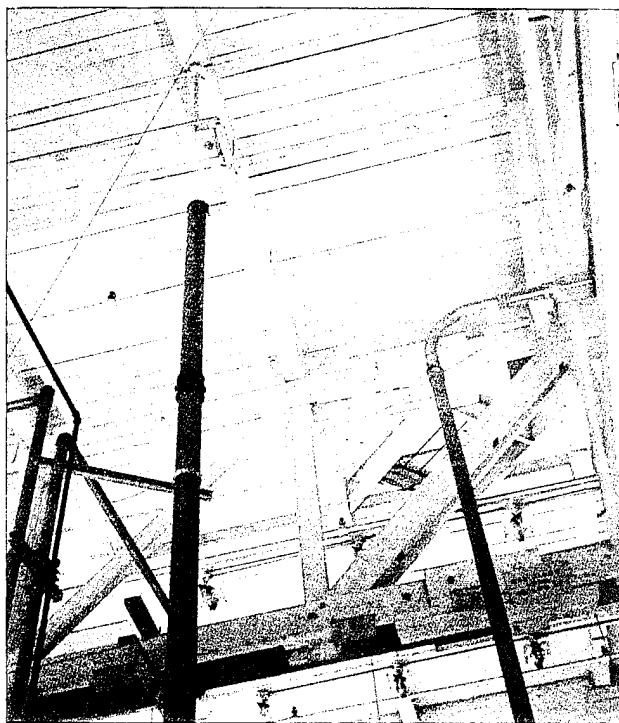
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Drip leg for AIVD system vent to atmosphere.

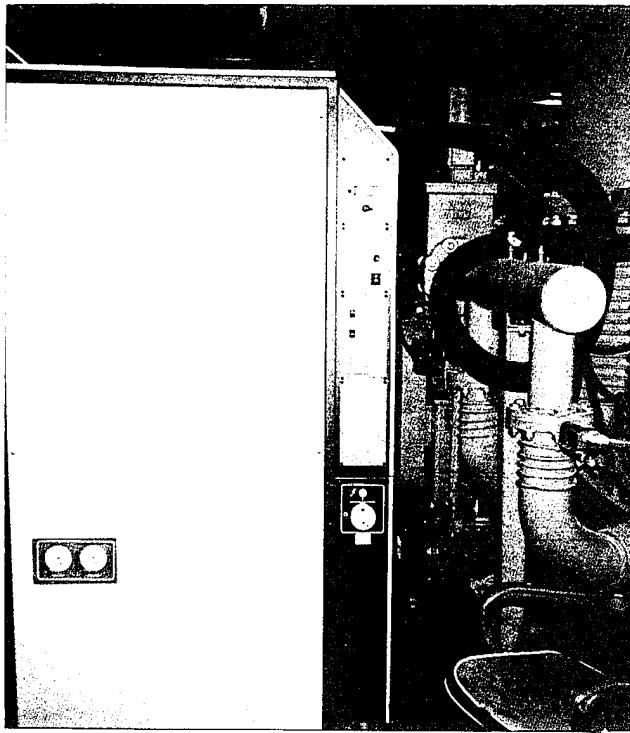


Roof penetration of AIVD system vent.

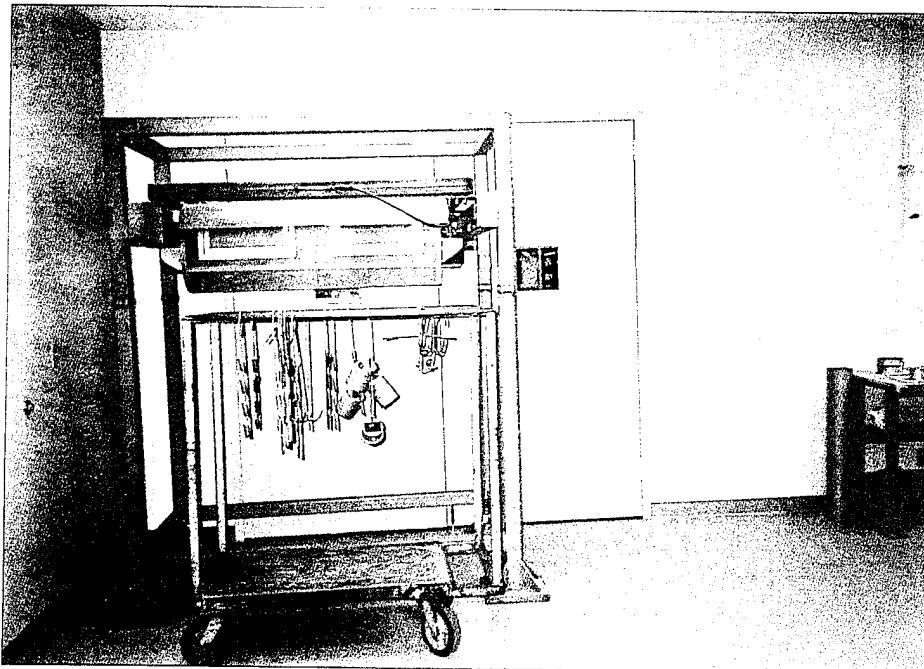
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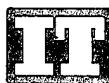


Cryogenic cooling system.

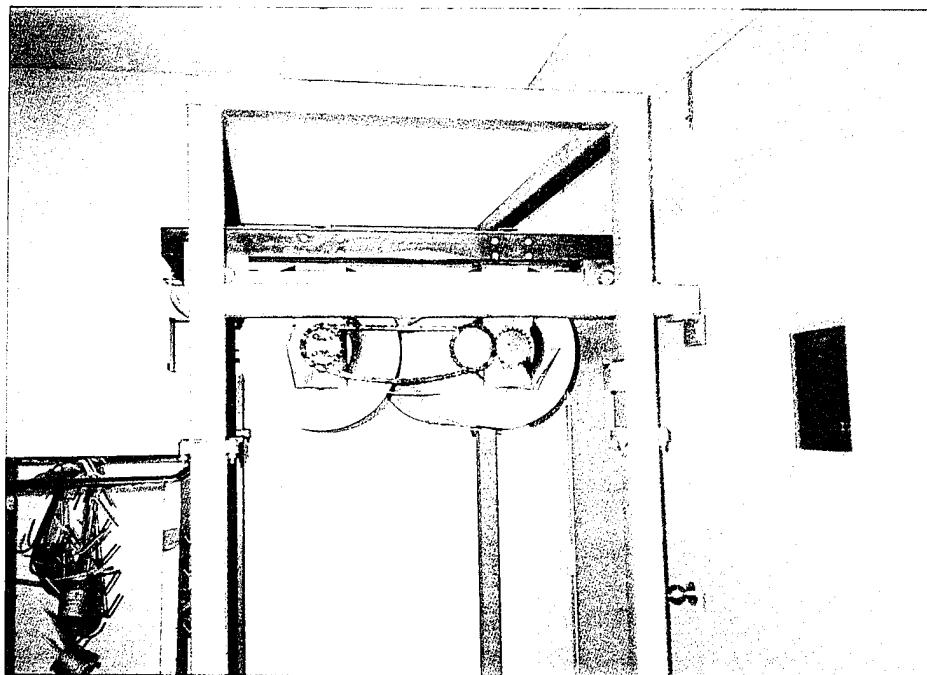


Front view of barrel coater.

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Side view of barrel coater.



Blast booth used for glass peening of AIVD coated parts.

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Appendix C

Trip Reports: TOAD

Minutes of Kickoff Meeting for Hazardous Waste Minimization Technology Transfer/Implementation Support for Depot System Command Installations

USAEC Contract No. DACA31-91-D-0074
Task Order No. 6
IT JTN 32244

November 30, 1993
Tobyhanna Army Depot
Tobyhanna, PA

Prepared by:

IT Corporation
Cincinnati, Ohio

A project meeting for the referenced Task Order was held on November 30, 1993 at the Tobyhanna Army Depot (TOAD), Tobyhanna, Pennsylvania. The purpose of the meeting was to identify tasks, responsibilities and schedules for procurement and installation of an Aluminum Ion Vapor Deposition (AIVD) system at TOAD. Key personnel responsible for various aspects of the project were introduced to facilitate communication and coordination between all parties involved. The following personnel participated in the meeting:

U.S. Army Environmental Center (AEC)

Dick Eichholtz - COTR 410/671-1561

Tobyhanna Army Depot (TOAD)

Pat Tierney - Prod. Eng. Div. 717/ 894-6724
Mike Parrent - Chief, Hazardous Waste Branch 717/ 894-6105

IT Corporation

Bob Hoye - Project Manager 513/ 782-4776
Rajib Sinha - Project Engineer 513/ 782-4694

Mr. Mark Viola of TOAD participated during the focused discussion of Army procurement requirements.

A summary of the major issues discussed is presented below.

Introduction and Background

TOAD supplies and maintains communication and electronic equipment to the U.S. Armed Forces. Currently, new fabrication work is increasing while overhaul work is decreasing. Approximately 40% of the current workload is overhaul. The workload varies considerably.

As part of it's operations, TOAD electrochemically coats some parts with cadmium. This operation results in the generation of cadmium-containing waste which is classified hazardous. In addition, abrasive blasting operations and hand sanding operations for cleaning and stripping of cadmium-coated equipment produce cadmium-containing hazardous waste. These wastes account for approximately 60% of the total hazardous waste generated by the facility.

TOAD is seeking to replace at least part of it's cadmium plating operations with an aluminum ion vapor deposition (AIVD) system. This would eliminate the waste generated from the plating operation, and, over a period of time as existing cadmium coated parts become aluminum coated or are phased out, reduce cadmium in the waste generated from the blasting operation.

Meeting Minutes

- In order to procure the AIVD equipment in FY 1995, the procurement package must be submitted to the depot contracting office by September 30, 1994. This is the absolute project deadline.
- AEC and Depot personnel identified the following topics as potential work elements of the AEC technical support project:
 - Preparation of specifications and procurement package for the AIVD and support equipment.
 - Research the use of AIVD in electronics/communications equipment to identify potential problems in substituting aluminum for cadmium in this field.
 - Assist in identifying applicable MIL specifications for cadmium coated parts.

- Assist in identifying parts that are cadmium coated and for which AIVD may be potentially applicable. TOAD currently does not have an inventory of such parts.
- Preparation of a proposed equipment layout. The AIVD equipment will most likely be located in Building 1B, Bay 1. However, the equipment may later be moved to a new facility being planned. The layout should include identification of ancillary equipment required.
- Identification of power and HVAC requirements for the system.
- Compilation of operating procedures, including maintenance requirements, for the AIVD equipment. Copies of operating procedures from other army depots (ANAD and CCAD) and Warner Robbins AFB should be available.
- Research current and potential future OSHA and EPA requirements for cadmium exposure.

- The AIVD procurement has been entered into IMMIS (Integrated Modernization Management Information System) by TOAD.
- Any depot project requiring funding in excess of \$500,000 requires Congressional approval.
- TOAD has begun preparation of a cost/benefit analysis for replacing cadmium plating with AIVD. IT could assist in the completion of this analysis and in the assembly of the final product. This Economic Analysis (EA) should be completed by the end of February, 1994. The EA has to be approved by 9/30/94. DESCOM typically requires 6 weeks to complete it's review of an EA. EA review and approval will occur in the the following sequence: Resource Management (RM), TOAD Commander, DESCOM, AMC, DA and Congress.
- Equipment bid specifications must be completed by September 30, 1994. For a first quarter, FY 1995, procurement, the specifications should be completed by May or June 1994, or approximately 180 days prior to procurement. TOAD will define the deadline for preparation of the specifications.
- TOAD will prepare the Purchase Request (PR) document, the Market Research document and the Technical Proposal Submission outlining bid requirements (eg. experience documentation, etc.) and the criteria for evaluation and selection of bids.

- TOAD will determine if a new air permit will be necessary for the aluminum oxide blasting and glass peening operations associated with the AIVD system. IT will check the exhaust requirements for these two operations.
- No specific safety requirements were identified. The TOAD Safety Department will review the equipment specifications. IT will acquire available information on the noise levels associated with AIVD equipment operation.
- Equipment installation will be done by TOAD Facilities Engineering. A Work Order Form will be prepared to document site requirements.
- IT will participate during visits to ANAD, CCAD and, possible, WR AFB to view AIVD installations at those locations. IT will prepare a memo listing the sites to be visited, a proposed agenda, and the schedule for the site visits. This will be provided to AEC and TOAD so that the visits can be coordinated between all parties.
- During the meeting, the following documents were provided to IT:
 - Draft copy of the EA being prepared by TOAD
 - Example EA
 - Copy of an example purchase request with specifications
- The following items were discussed and will be provided to IT:
 - Blank Work Order Form
 - Floor plan for the proposed location of the AIVD
 - Maximum allowable floor loading of Building 1, Bay 1
- TOAD will prepare a list of parts coated, the quantities coated, and the clients involved.
- IT will prepare a pert chart for the project identifying the critical path using information provided by TOAD.

Action Items

1. Contact Vendors of AIVD equipment for information on: - equipment size and floor loadings - ancillary equipment required - power and HVAC requirements including the need for any roof penetration	IT
2. Prepare a memo listing sites to be visited to view AIVD equipment. Prepare the agenda for each site visit	IT
3. Provide information to IT for preparation of a project pert chart.	TOAD
4. Prepare a pert chart for the project identifying the critical path.	IT
5. Begin investigating OSHA and EPA requirements for cadmium.	IT
6. Begin investigation the use of AIVD in electronics/ communications.	IT
7. Prepare Purchase Request, Market Research and Technical Proposal Submittal.	TOAD
8. Identify and define additional deadlines for preparation of the bid specifications.	TOAD
9. Determine air permit requirements for AIVD equipment.	TOAD
10. Prepare a list of parts coated, the quantities coated, and the clients involved.	TOAD

**Minutes of Site Visit and Project Meeting
for
Hazardous Waste Minimization Technology Transfer/Implementation
Support for Depot System Command Installations**

Contract No. DACA31-91-D-0074
Task Order No. 6
IT JTN 322244

May 2 & 3, 1995

Tobyhanna Army Depot
Tobyhanna, PA
and
Letterkenny Army Depot
Chambersburg, PA

Prepared by:
IT Corporation
Cincinnati, OH

Site visits and project meetings for the referenced Task Order were held on May 2 and 3 at the Tobyhanna Army Depot (TOAD) and Letterkenny Army Depot, respectively. The purpose of the visits and meetings was to discuss overall project status and receive an update on the status of site specific activities related to aluminum ion vapor deposition (AIVD) at TOAD and methylene chloride contamination in rinse waters at LEAD. The following personnel participated in the meetings:

Pat Tierney - TOAD, SDSTO-ME-E	717/894-6724
Todd Johnson - LEAD, SDSLE-MME	717/267-9506
James Heffinger, Jr. - USAEC, ETD	410/612-6846
Bob Hoye - IT Project Manager	513/782-4776
Rajib Sinha - IT Project Engineer	513/782-4694

A summary of the major issues discussed is presented below:

TOAD - Mr. Tierney indicated that the construction of the new plating shop, that would house the AIVD system, has been delayed significantly. He anticipates that the new facility is at least 3 years away, procurement of the AIVD system is currently

planned for FY99. During the meeting, several areas of potential technical assistance were discussed and are summarized below.

The design for the new plating building is proceeding. USAEC/IT could review the 60 percent design package for the proposed location of an IVD system. The schedule for the availability of the design package is not known and any review would likely be conducted on a short notice, rapid response basis.

Mr. Tierney will determine if private/commercial work can be conducted on-depot with an IVD system (i.e., partnering). Mr. Heffinger indicated that this might favorably impact the economic analysis for an IVD. If the potential exists, USAEC could assist the depot in conducting a market analysis.

The process that must be followed to requalify IVD parts (e.g., for substitution of aluminum for cadmium coatings) was discussed. The process has not been defined for parts at TOAD. The USAEC task could include further interaction/technology transfer with ANAD and CCAD to document the requalification process used by other depots and/or IT could work with Mr. Tierney to define the process at TOAD.

The National Defense Center for Environmental Excellence (NDCEE) was discussed. Concurrent Technologies Corporation (CTC), operator of the NDCEE is planning to acquire and install an IVD system. Specific interaction was not identified, however, an IVD system at the NDCEE could potentially be used for testing on TOAD specific parts, operator training, etc.

Mr. Tierney will obtain and provide an updated listing of cadmium wastes generated and their generation rates.

Other potential uses of IVD were discussed including plating of plastic parts. IT will obtain additional information this potential alternate application. Additionally, the elimination of cadmium plating requirements from part specifications was discussed.

Mr. Tierney also provided comments on the Economic Analysis (EA) previously submitted by IT. He provided updated rates (e.g., labor rates) and corrected the description of cadmium plating at TOAD (i.e., cyanide not used in cadmium baths)

Action items identified during the project meeting at TOAD are summarized below:

IT - Revise EA to reflect comments received.

Review available information on requalification of parts coatings, discuss with ANAD and CCAD, prepare summary memorandum to document initial findings.

Assess use of IVD on plastic parts and on electronics.

TOAD- Determine schedule of 60 percent design review for plating facility and need for IT review.

Determine feasibility for partnering with private/commercial IVD work on-depot.

Provide updated listing and generation rates for cadmium wastes.

LEAD - The need for implementation of the Sampling and Analysis Plan to characterize paint stripping rinse waters in Buildings 350 and 370 was discussed. LEAD has recently been using an alternate (non-methylene chloride) paint stripper in Building 370. The new stripper is Turco® 6088A, a copy of the MSDS is attached. This is the same stripper that Red River Army Depot (RRAD) has been using. The new stripper is not as fast as the methylene chloride formulation but has been well received by the shop operators and gives satisfactory removal of CARC and other paint systems. Current plans are to replace methylene chloride stripper in both buildings with the Turco® product. This will negate the need for evaluation of methylene chloride in the water and steam rinse tanks.

It was agreed that the USAEC's methylene chloride characterization effort would be suspended unless the Turco® stripper proves unsatisfactory in the near term. In order to close out this effort, IT will prepare a document that summarizes project background, scope, and resolution. The Test and Safety Plans will be included as appendices. Mr. Johnson will provide available characterization data, from the waste characterization forms prepared for the most recent disposal of rinse water (Building 370) and steam rinse residue (Building 350). This information will be included in the project summary.

Mr. Johnson indicated that he is interested in pursuing IVD technology for LEAD. He is currently in the initial phase of assessment. It was agreed by all that IT would provide relevant project information to supplement his data base. Trip reports, vendor information, and process information previously submitted to USAEC and TOAD by IT will be forwarded to Mr. Johnson. Information needed to complete the assessment include development of an understanding of the IVD process and how much of LEAD's work load could be plated by IVD versus conventional plating. (Currently the depot ships parts off-site for cadmium plating.) Mr. Johnson expressed interest in IVD plating of metals other than aluminum. LEAD currently uses brush plating for several specific applications. Mr. Johnson will obtain and provide a list of the metals that are brush plated. He indicated that LEAD may process several parts that are similar to parts coated by IVD at ANAD.

Mr. Johnson is planning to respond to the Army Remanufacturing and Reclamation (R&R) Thrust Area Program Call for FY96-02 Projects with an IVD acquisition request. A copy of the call for projects is attached. The depot recently

acquired a super critical carbon dioxide cleaning system through a similar mechanism.

A tour of the paint stripping operations conducted in Buildings 350 and 370 was also conducted during the visit.

Action items identified during the project meeting at LEAD are summarized below:

IT - Prepare summary of methylene chloride task to close out this activity.

Provide copies of IVD background material and trip reports.

LEAD - Provide a list of metals that are currently applied by brush coating.

Appendix D
Waste Generation Rates at TOAD

CY 92 ANNUAL HAZARDOUS WASTE GENERATION MINIMIZATION REPORT

**Hazardous Waste Minimization Technology Transfer/Implementation
Support for Depot System Command Installations**

Provided by:

Mr. Michael Parrent - Chief, Hazardous Waste Branch
Tobyhanna Army Depot
May 1994

CF322244
M2-1992 Waste
Rates
CY 92 waste
gen

ANNUAL HAZARDOUS WASTE GENERATION MINIMIZATION REPORT

INSTALLATION NAME: Tobyhanna Army Depot POC: Wendy Gross, AV 795-6560

01 January - 31 December 1992

A. HAZARDOUS WASTE GENERATION AND MINIMIZATION TABLE

EPA Code	Unit	<u>1985 Baseline Generation</u>		Fate KG/ Fate Code	KG	<u>CY1992 Generation</u>	<u>1992 Goal</u>
		KG/Yr/Unit	KG/Yr/Unit				
ELECTROPLATING							
D002, D006	Acids	11,722	13,032	13,032/E	5,861		
D007, D008							
D002, D006	Alkaline	1,548	1,247	1,247/E	774		
D007, D008							
D002	Paint Sludge	864	0	0	432		
D001, D002	Paint Stripper	2,545	811	811/E	1,273		
D006, D007							
D008, F002							
D002, D006	Filter Tubes	682	290	290/E	341		
D002, D007	Chromium Waste	2,182	99	99/E	1,091		
D002, D006	Cadmium Plating Bath	4,000	0	0	2,000		
D011	Silver Plating Bath/Carbon Sludge	0	0	0	5		
D006, D011	Silver Bath Filter Tubes	0	53	53/E	(1992)		
D011	Sludge from Nickel Filters	0	0	0	86		
D006, D007	OD Iridite	0	1,438	1,438/E	(1992)		
D008							

<u>1985 Baseline Generation</u>			<u>CY1992 Generation</u>	<u>1992 Goal</u>
<u>EPA Code</u>	<u>Unit</u>	<u>KG/Yr/Unit</u>	<u>KG/Yr/Unit</u>	<u>Fate KG/ Fate Code</u>
ELECTROPLATING Cont.				
D006, D007	Nckel Solvent	0	1,957	1,957/E (1992)
D006, D007 D006, D010	Aluminum Etch	0	2,991	2,991/E (1992)

Nomenclature changes during disposal procedures has caused the reclassification of waste in the Generation and Minimization tables.

PRINTED CIRCUIT BOARD

D002, D006 D007, D008	Acids	2,762	4,292	4,292/E	1,363
D002	Alkaline	11,455	3,660	3,660/E	5,728
D001, D002	Oxidizer	3,455	898	898/E	1,728
F002	Solvent	364	226	266/E	182
F008	Gold Filter	0	103	103/E	(1992)
D008, F009	Gold Stripper	0	205	205/E	(1992)
F008	Gold Resin	0	47	47/E	(1992)
	Citrate Sulfide Solvent	0	355	355/E	(1992)

PAINT SHOP

D001, D018 F003, F005	Paint Thinner	2,000	1,535	1,535/E	1,000
F005, F003 D001	Paint Thinner Rags	0	1,802	1,802/E	1,093 (1990)*
F001, D002 D001, F002	Paint Stripper	23	0	0	12
D001, F003 F005	Paint Waste	70,000	28,076	28,076/E	35,000

*Year first generated.

1985 Baseline Generation

CY1992
Generation 1992 Goal

<u>EPA Code</u>	<u>Unit</u>	<u>KG/Yr/Unit</u>	<u>KG/Yr/Unit</u>	<u>Fate/KG</u>	
				<u>Fate Code</u>	<u>KG</u>
PAINT SHOP CONT.					
F005, F003	Paint Filter	0	6,239	6,239/E	7,584 (1988)
D001, D002 F002	Paint Strip Debris	0	241	241/E	350 (1992)

SANDBLAST SHOP

D008, D007 D006	Sandblast Grit and Debris	70,738	28,539	28,539/E	35,369
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ULTRASONICS

D001, D006	Stoddard Solvent	5,273	153	153/E	2,637
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OTHER SHOP

F002	PCE Solvent	727	0	0	364
F005, F003 F002, F001	Aerosol Cans	0	0	0	170 (1990)
F002, D001	Oil with TCE	0	0	0	273 (1990)
F002	TCE and Trichlorotri- fluoroethane	0	0	0	91 (1990)
D001, F001	Solvent Rags	0	83	83/E	16 (1991)
D001, F002 F003, F005	Solvent Rags	0	350	350/E	226 (1991)
D001, F001 F003, F005	Solvent Rags	0	19	19/E	17 (1991)
D006	Sulfide Sand	0	2,048	2,048/E	660 (1991)

<u>1985 Baseline Generation</u>			<u>CY1992 Generation</u>	<u>1992 Goal</u>	
<u>EPA Code</u>	<u>Unit</u>	<u>KG/Yr/Unit</u>	<u>KG/Yr/Unit</u>	<u>Fate/KG</u>	
				<u>Fate Code</u>	<u>KG</u>
OTHER SHOP CONT.					
D002, D007	Iridite Rags	0	118	118/E	60 (1991)
D006, D007 D010	Sodium Hydroxide Solid	0	0	0	16 (1991)
F002	Oil and TCA	0	57	57/E	58 (1991)
F001, F002	Sonic Solvent	0	234	234/E	407 (1991)
D003	Lithium Batteries	0	90	90/E	44 (1991)
D002, D006	Nickel Cadmium Battery	0	812	812/E	(1992)
D007	Magnesium Battery	0	236	236/E	(1992)
D009	Mercury	0	7	7/E	(1992)
D001	Toner	0	65	65/E	(1992)
D001	Isopropanol	0	94	94/E	(1992)
GRAPHIC MATERIALS					
D002	Developer	7	0	0	4
D001	Dry Imager	0	0	0	1 (1990)
D001	Silk Screen Ink	0	0	0	4 (1990)
DEPOT EQUIPMENT					
D001, D018	Diesel Fuel/ Gasoline	0	217	217/E	2,270 (1989)

<u>1985 Baseline Generation</u>		CY1992 <u>Generation</u>		<u>1992 Goal</u>	
<u>EPA Code</u>	<u>Unit</u>	<u>KG/Yr/Unit</u>	<u>KG/Yr/Unit</u>	<u>Fate/KG</u>	<u>Fate Code</u>
DEPOT EQUIPMENT CONT.					
D006, D008	Oil/Oil Filters	0	810	810/E	120 (1991)
D003	Pit Sludge	0	826	826/E	(1992)
MAINTENANCE OPERATION					
D001	Petroleum Naptha	0	2,932	2,932/0	1,616 (1989)
D001, D006, D007, F003, F005, D008	Paint Gun Cleaner	0	1,460	1,460/0	(1991)
WASTE TREATMENT SLUDGES					
D006	Sewage Sludge*,**	548,682	28,591	28,591/E	219,473
F006, D006	Sulfide Sludge	34,364	9,452	9,452/E	13,746
U.S. ARMY MEDICAL MATERIAL AGENCY					
D008, D007 D006	Sandblast Debris	9,864	678	678/E	4,932
D008, F003 F005	Paint Filters	0	282	282/E	142 (1990)
D001, F003 F005, D018 D040	Paint	0	354	354/E	385 (1990)
ENTOMOLOGY					
P122	Rodenticide	.45	0	0	0

CY 93 HAZARDOUS WASTE GENERATIONS WITH D006 (CADMIUM)
CLASSIFICATION

Hazardous Waste Minimization Technology Transfer/Implementation
Support for Depot System Command Installations

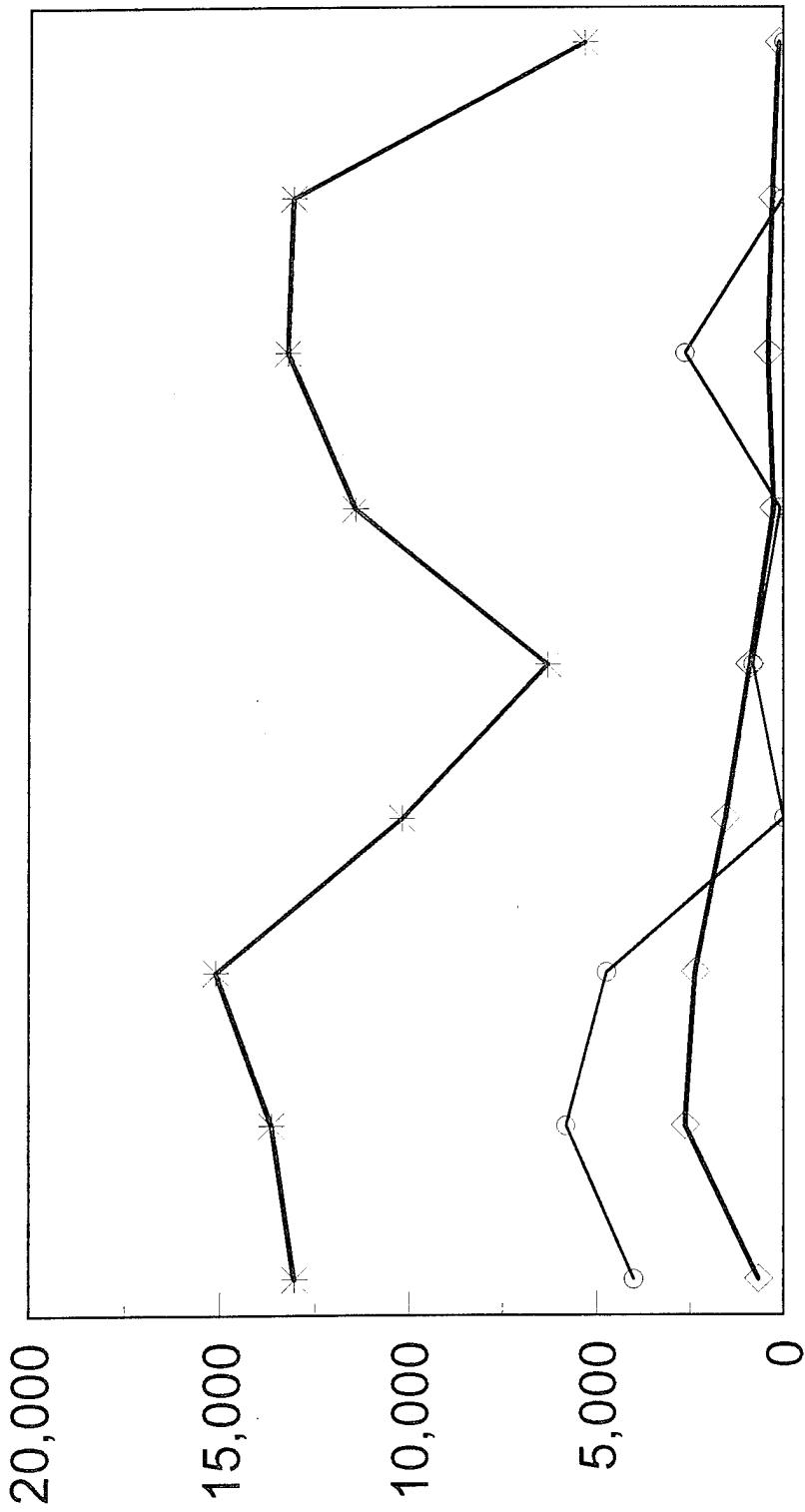
Provided by:

Mr. Michael Parrent - Chief, Hazardous Waste Branch
Tobyhanna Army Depot
May 1994

TOAD

Profile #	Description	EPA codes	# containers	weight	Cost
5EW64042	stoddard solvent	D1,6	1	360	\$126.00
US04	tetrachloroethylene/stoddard solvent	D6,39,F1	1	605	\$223.85
% Recycled	paint gun cleaner thinner	D1,6,F3,5	84	4,111	\$13,055.44
US02	steam sump sludge (detergent /wear metals)	D1,6,7,8,35,F3,5	4	338	\$107.26
US03	steam sump sludge (detergent /wear metals)	D6,7,8	4	487	\$161.89
% Fuel blended	paint gun cleaner thinner	D1,6,F3,5	91	614	\$1,950.81
S101	Sandblast grit	D6,7,8	58	34,818	\$12,186.30
S902	paint dust	D6	11	3,748	\$1,311.80
PL27	epoxy paint stripper (MeCl)	D2,6,7,8,F2	3	1,086	\$336.66
PL41	NaOH soln (small lye tank)	D2,6	1	189	\$86.94
S102	Sandblast filters	D6,7,8	3	793	\$277.55
S901	epoxy paint strip debris (rags, MeCl))	D6,7,F2,3	12	287	\$321.44
S904	Sandpaper, coveralls, gloves	D6	85	13,470	\$5,239.05
PL19/43	Cadmium filter tubes	D2,6	6	266	\$284.95
PL48	Carbon	D6	1	22	\$7.70
5EW62007	olive drab iridite (formic acid)	D6,7,8	2	895	\$411.70
PL16	nickel strip (sulfuric acid)	D2,6,7	5	1,223	\$562.58
PL17	metal plating waste zincate (NaOH)	D2,6,7,8	3	129	\$59.34
PL25	aluminum etch (NaOH)	D2,6,7,8,10	3	1,156	\$531.76
PL28	Brite dip (sulfuric/nitric)	D2,6,7,8	14	4,853	\$2,232.38
PT01	IWTP sand w/sulfide	D6	6	4,197	\$1,504.99
PT02	IWTP sludge	D6,F6	45	20,504	\$10,392.01
5EW62009A	phosphate sludge (Keykote #32)	D2,6	1	546	\$251.16
5EW62021	ferlon strip (NaOH)	D2,6,7,8	4	1,950	\$897.00
PL09	zinc phosphate	D2,6	2	910	\$418.60
PL14	ferric chloride soln	D2,6,7,8	8	4,102	\$1,886.92
PL15	black magic (NaOH)	D2,6,7	2	1,034	\$475.64
PL50	debris (wood)	D6,7	1 box	942	\$329.70
PL51	steel tank (nickel)	D6,7	1	818	\$286.30
3QC00001	Oil filters	D6,8,10	2	180	\$66.60
		Totals	463	104,633	\$55,984.32

Cadmium through the years (kg)

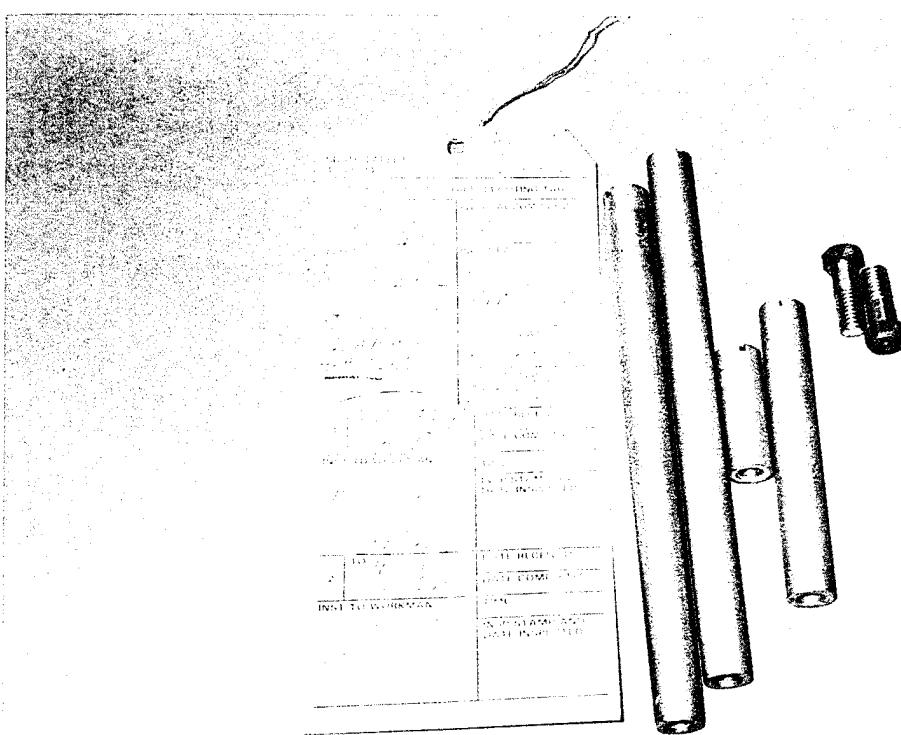
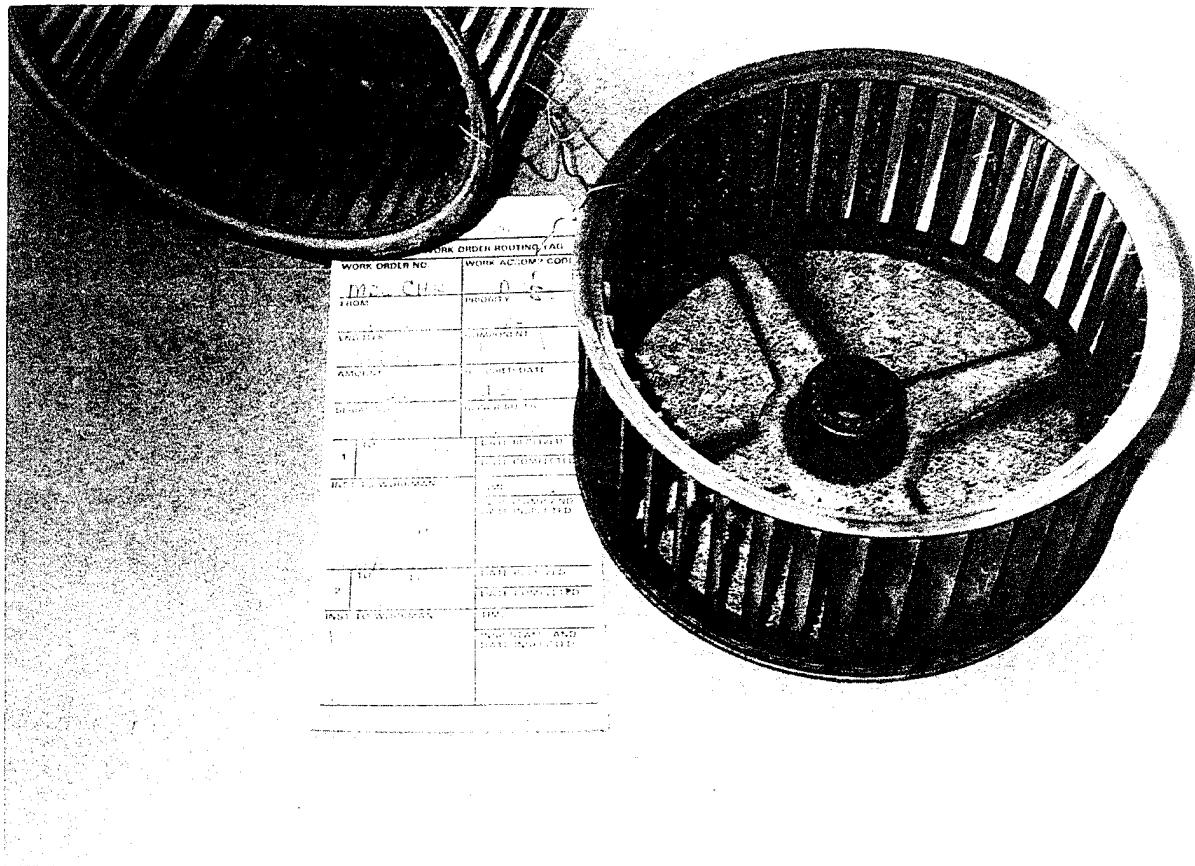


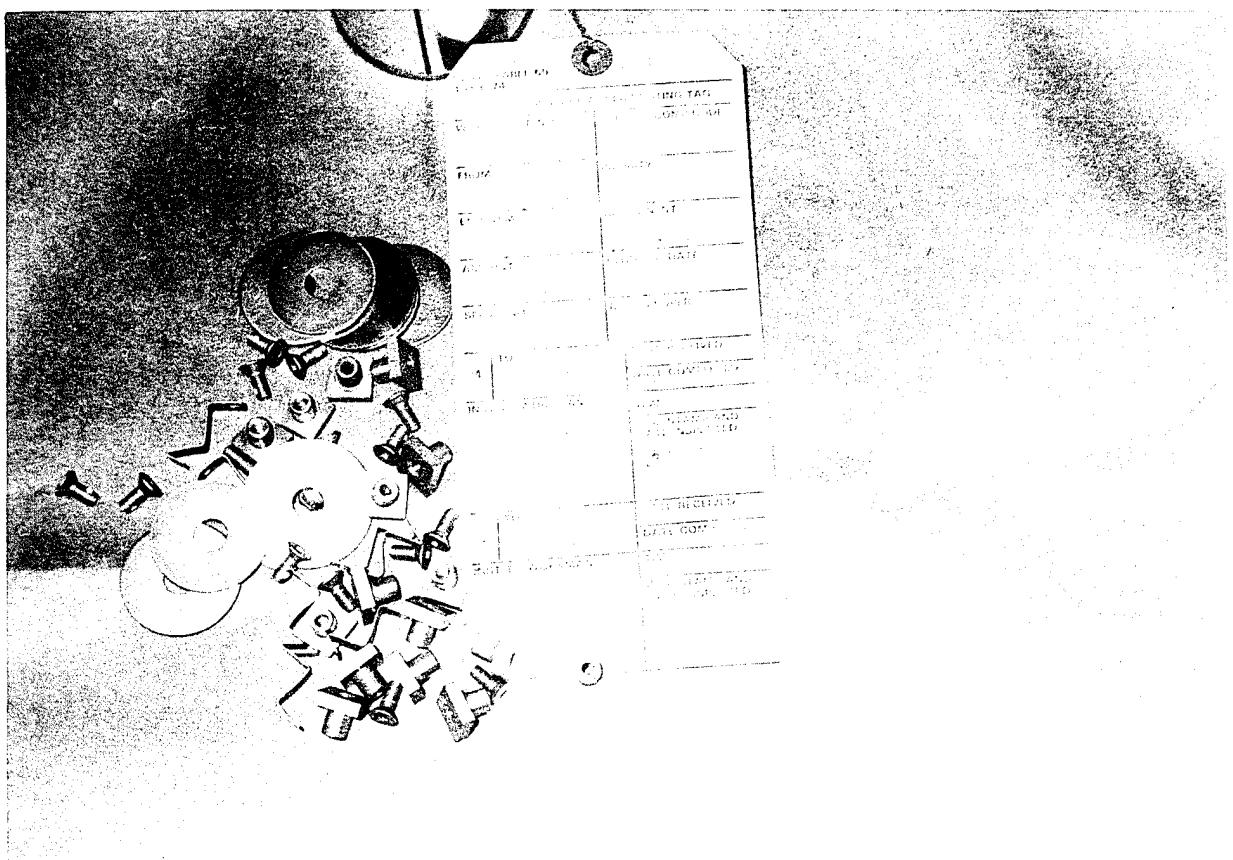
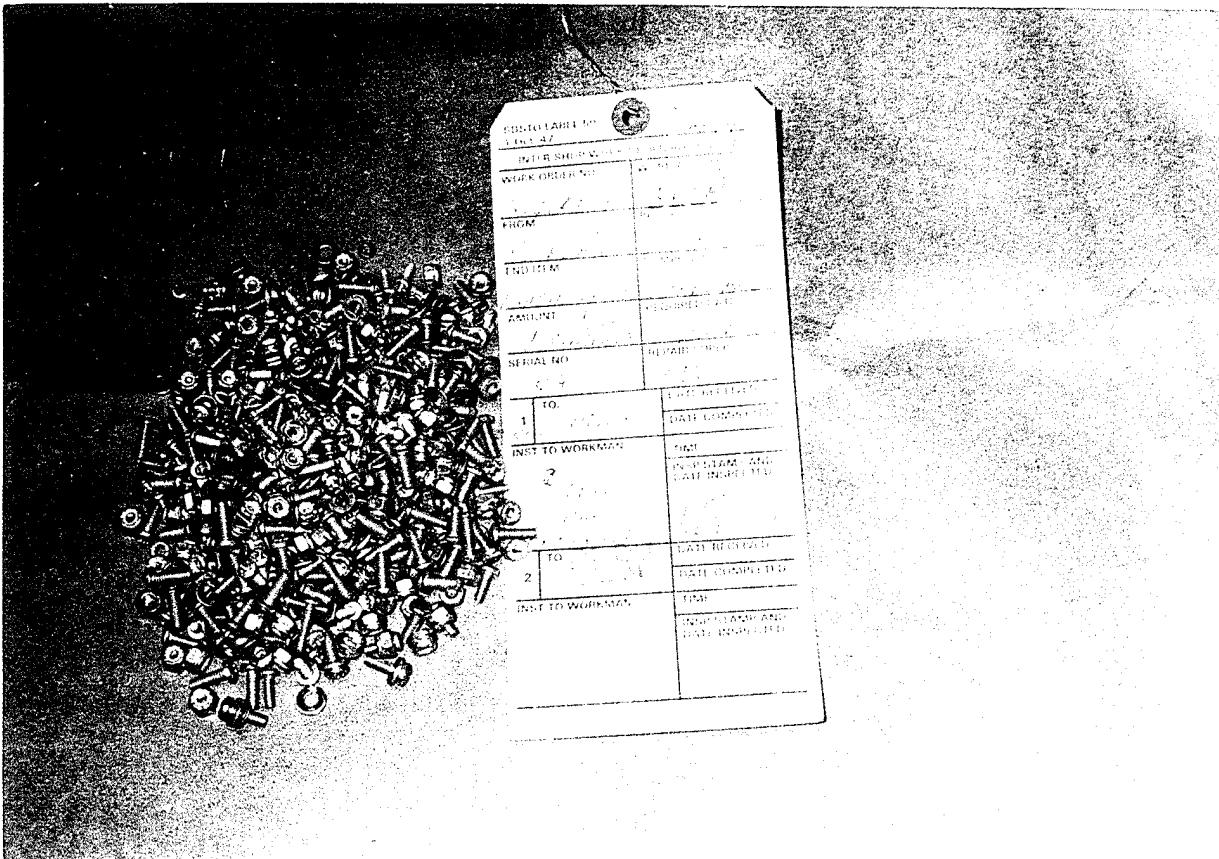
	1985	1986	1987	1988	1989	1990	1991	1992	1993
Cad Bath	4,000	5,818	4,728	0	817	93	2,623	0	0
Filter Tubes	682	2,632	2,364	1,566	908	268	405	290	121
HCl Bath	13,032	13,636	15,090	10,181	6,292	11,405	13,196	13,032	5,300

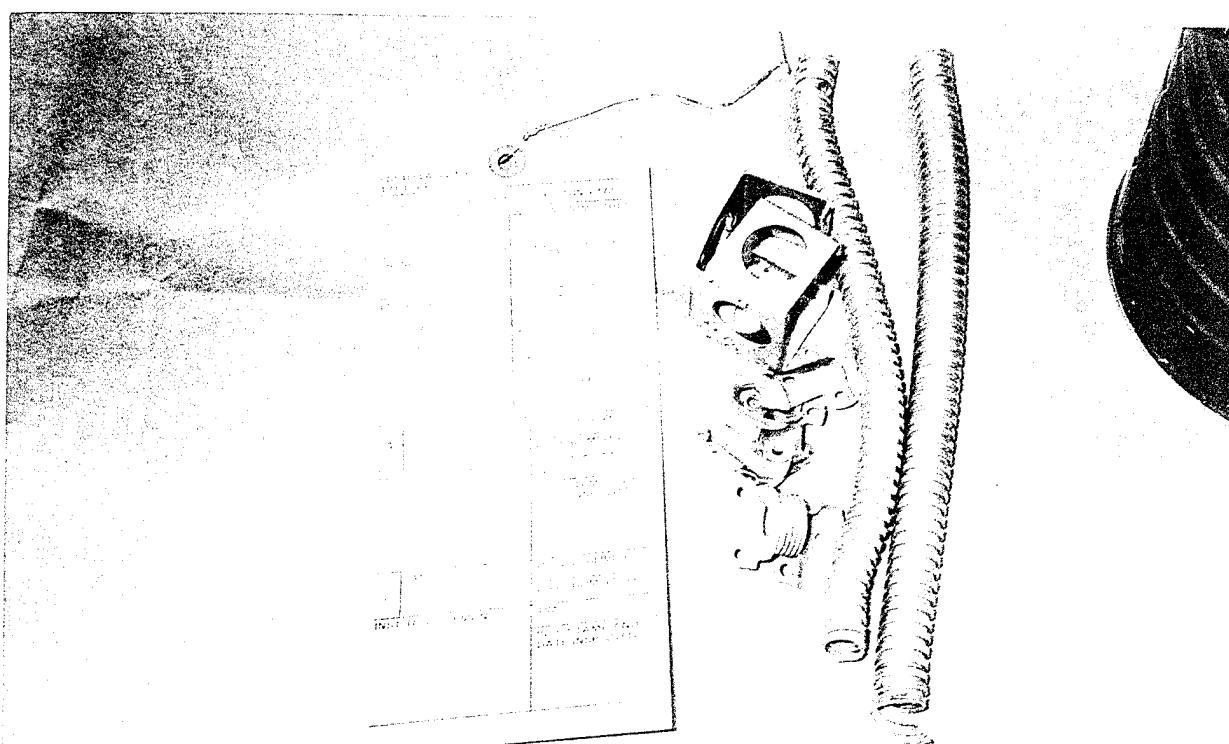
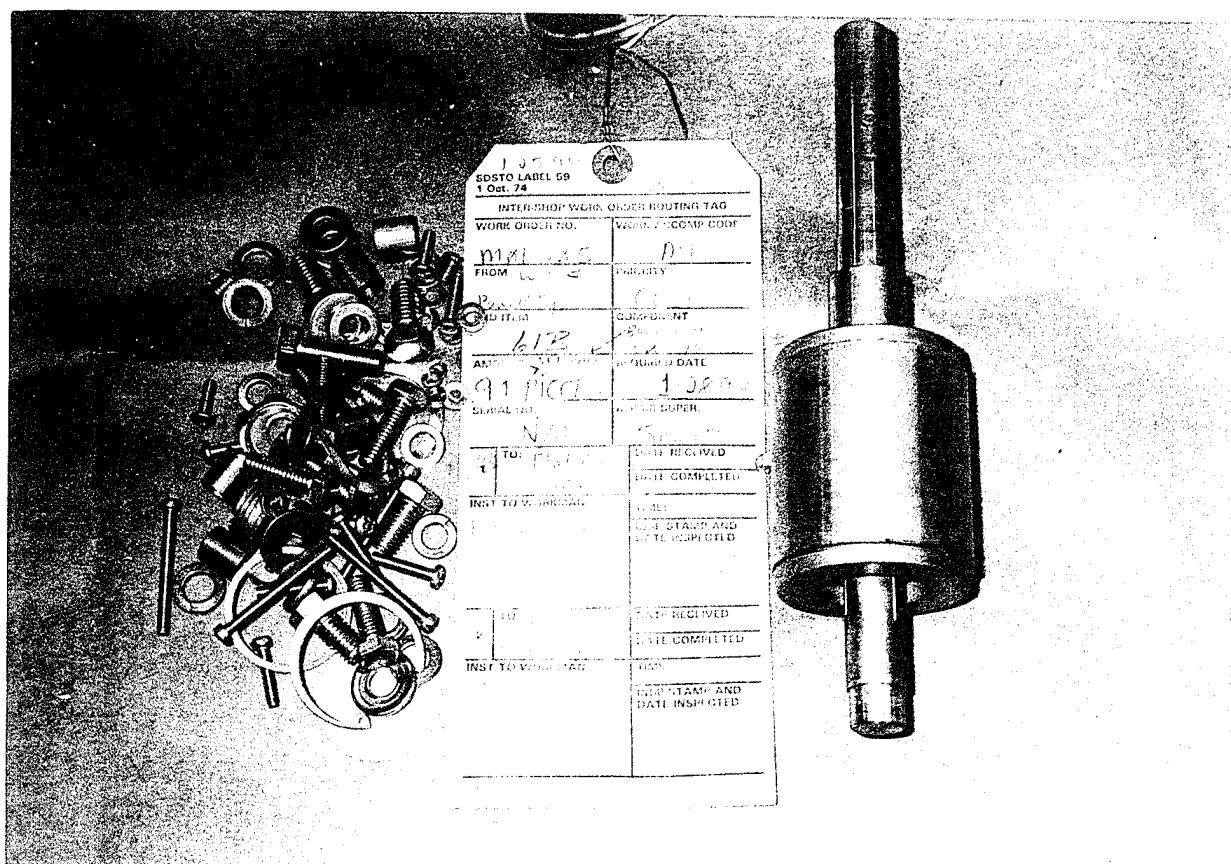
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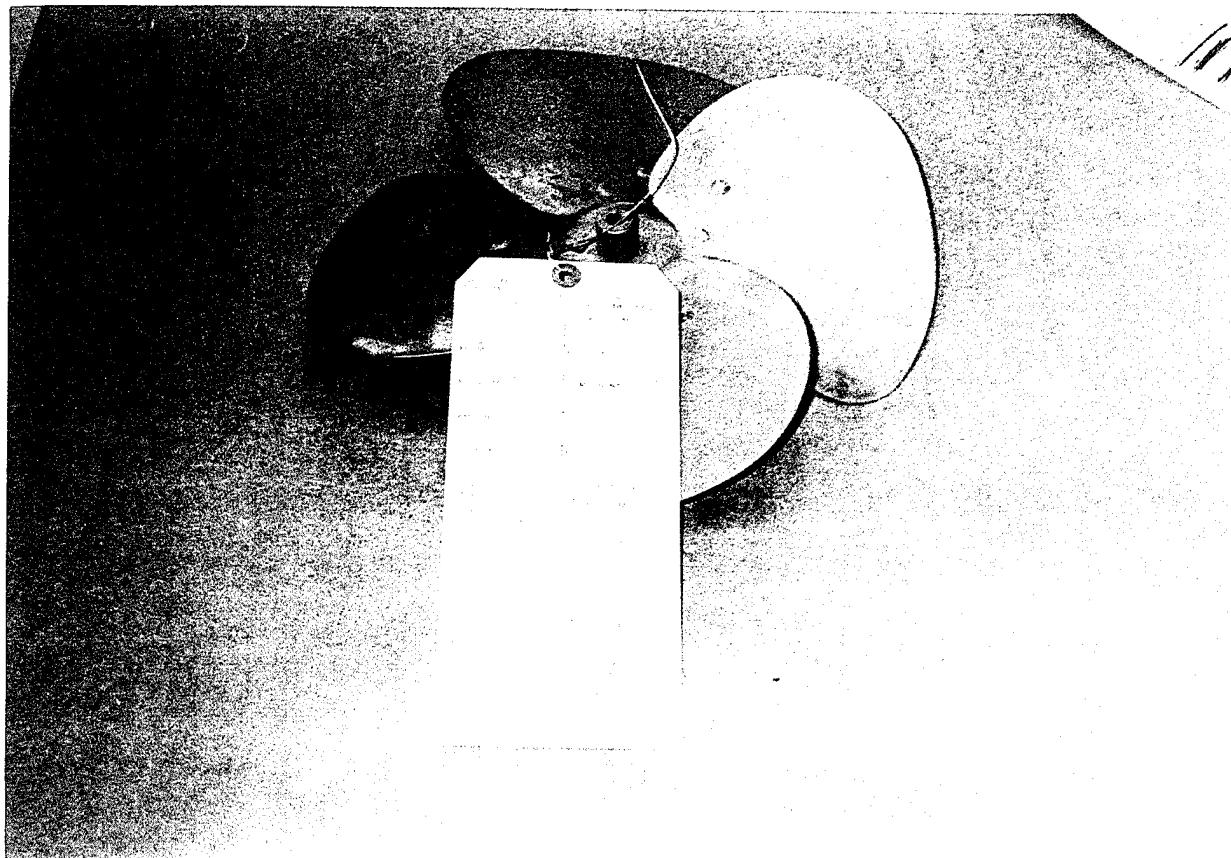
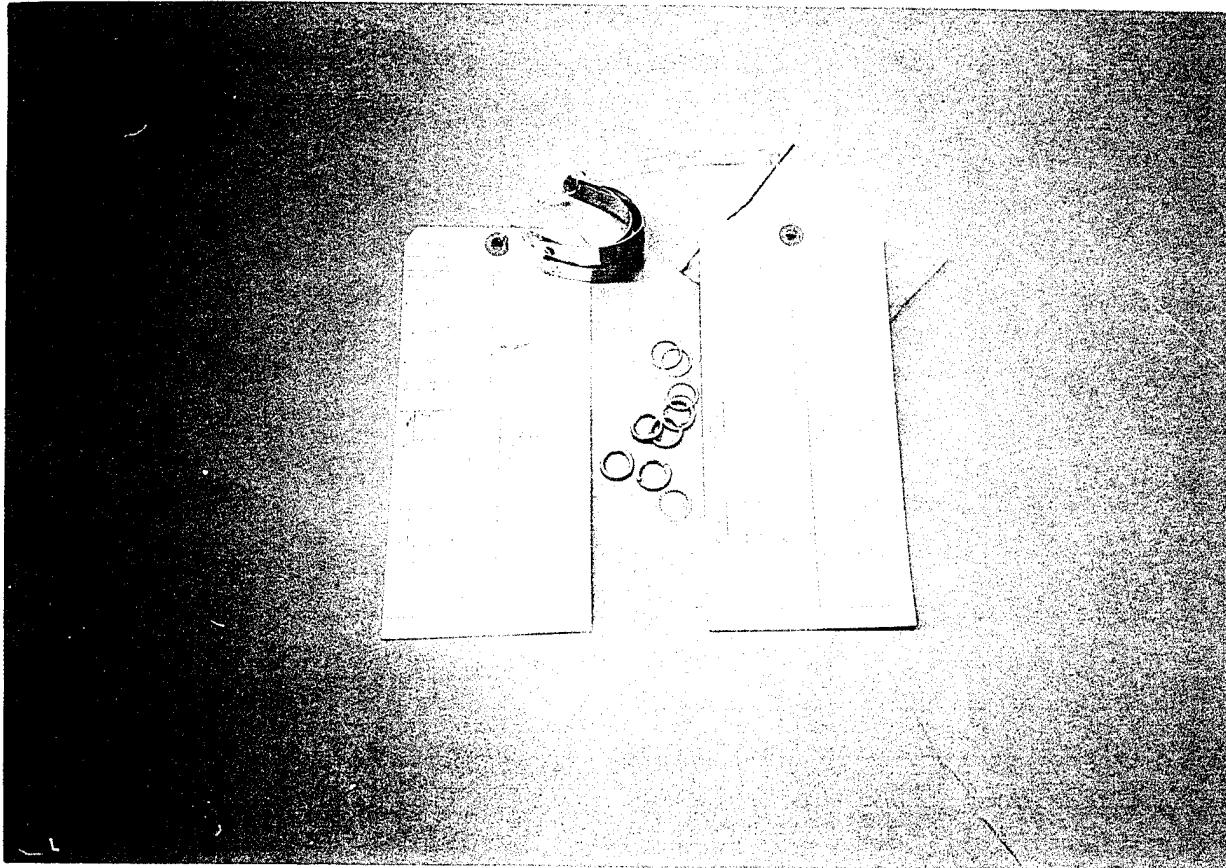
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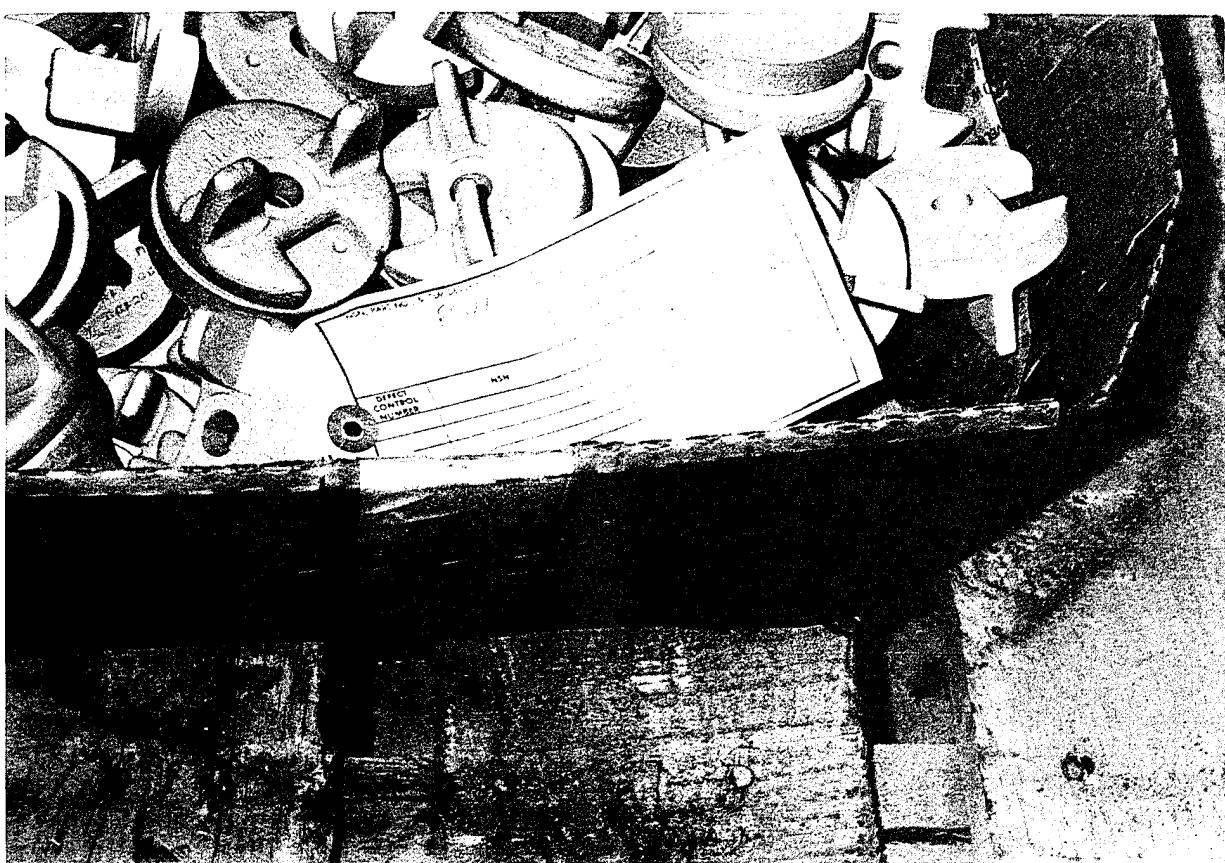
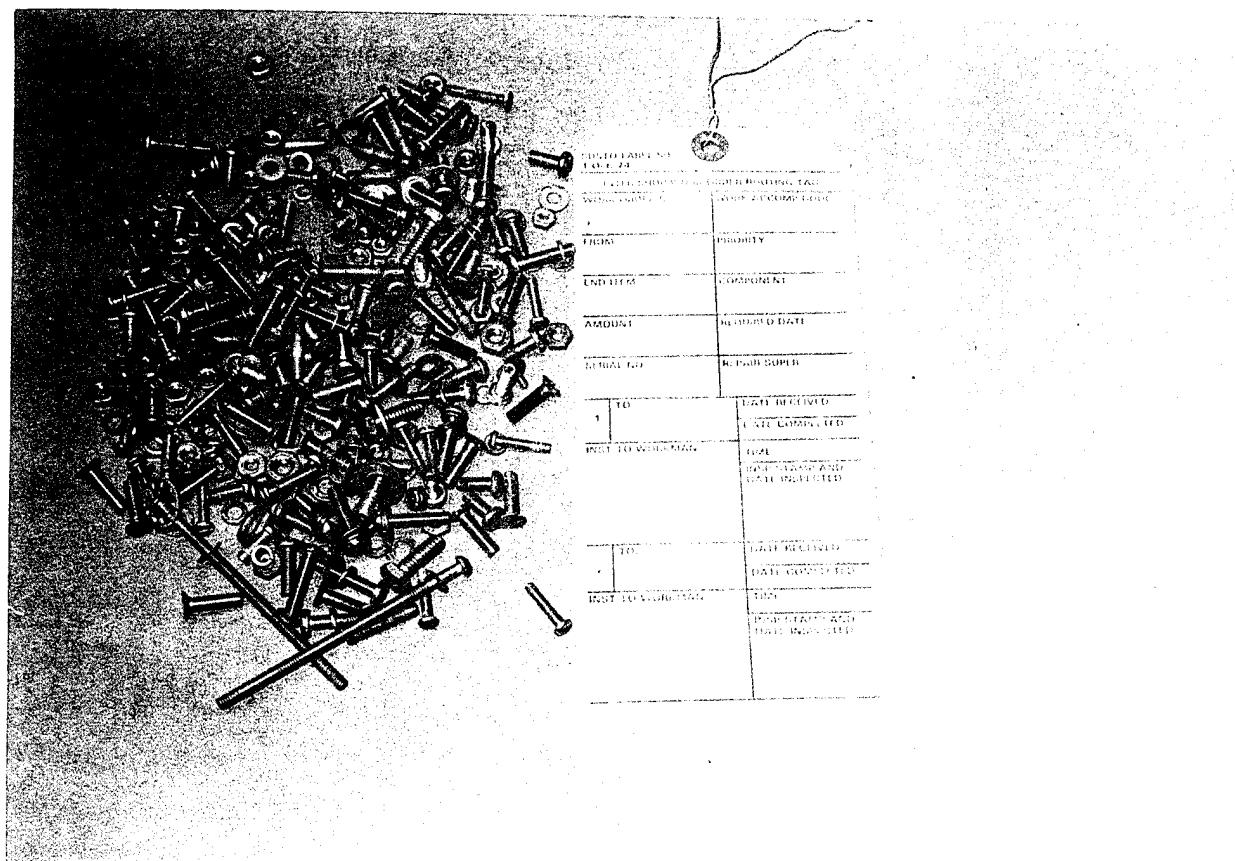
Photographs of Typical Cadmium Plated Parts Handled at TOAD

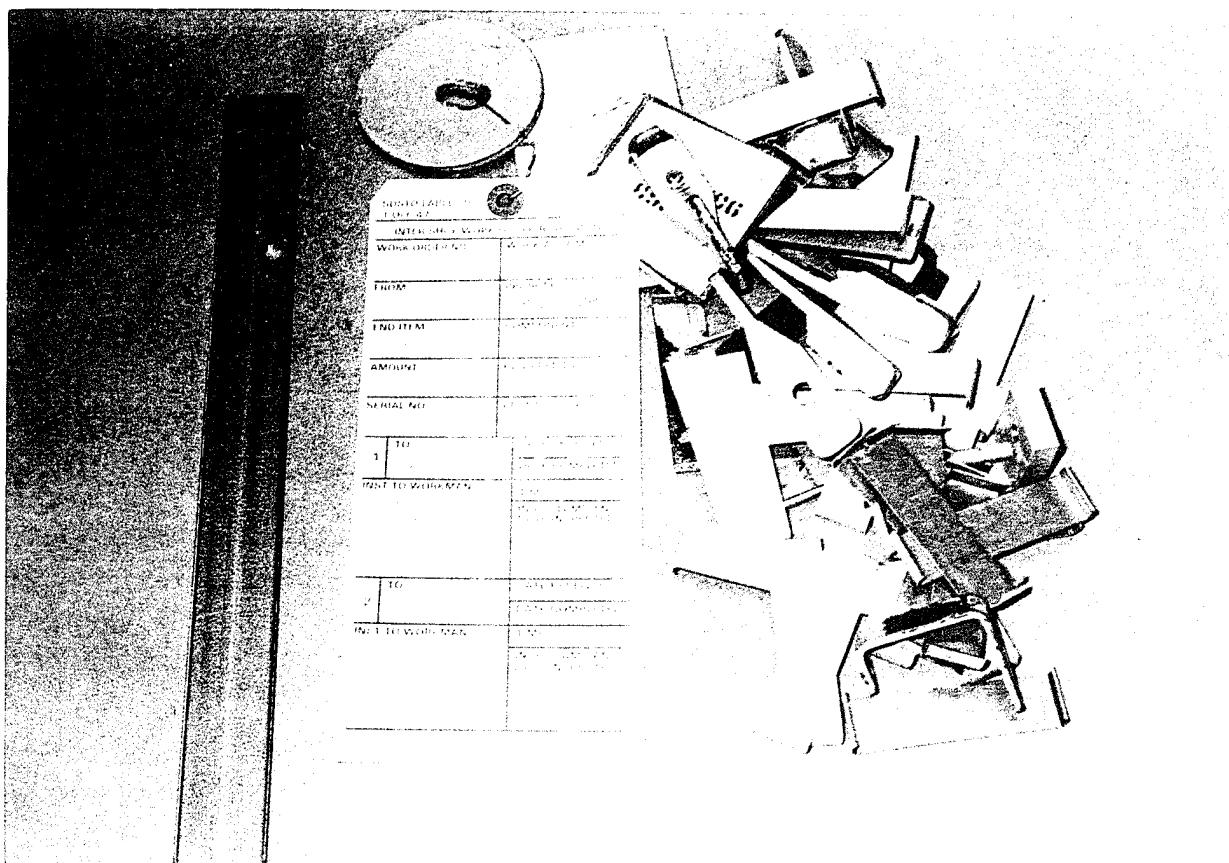
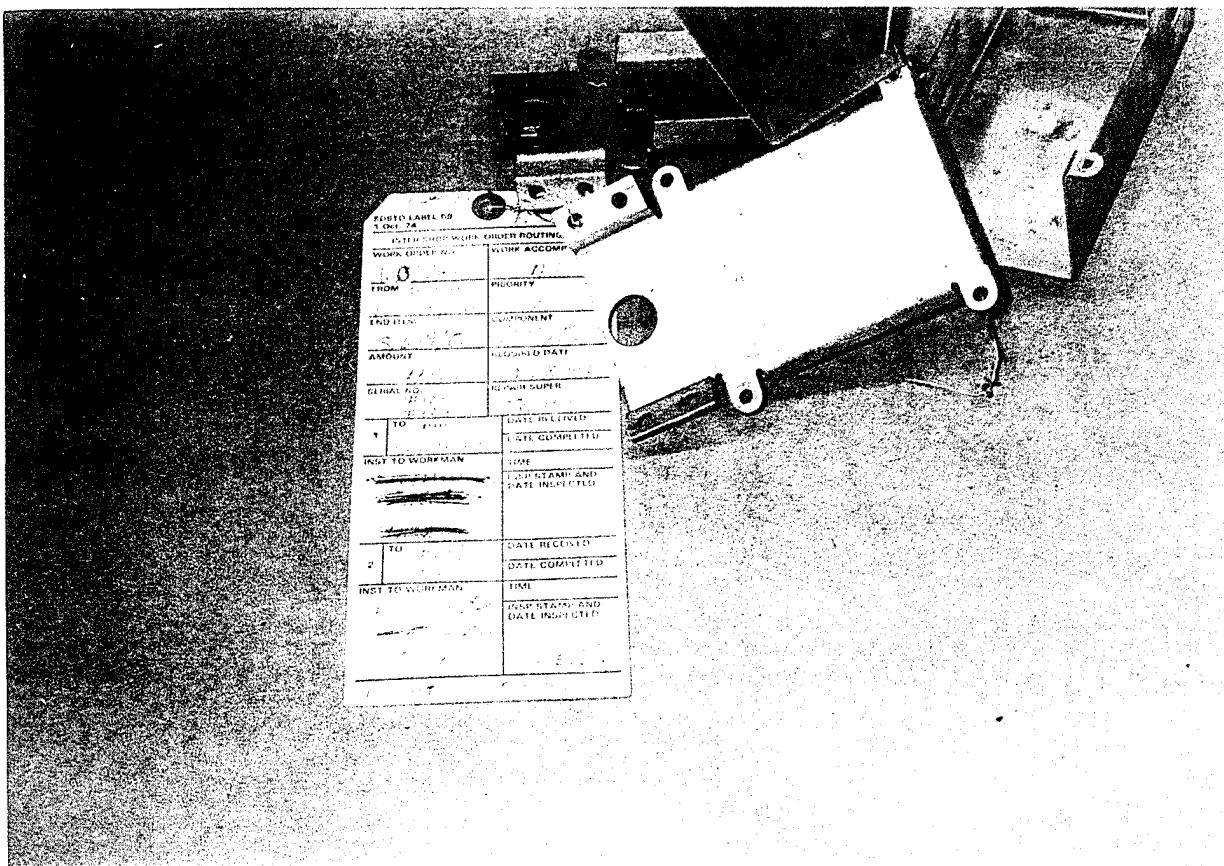






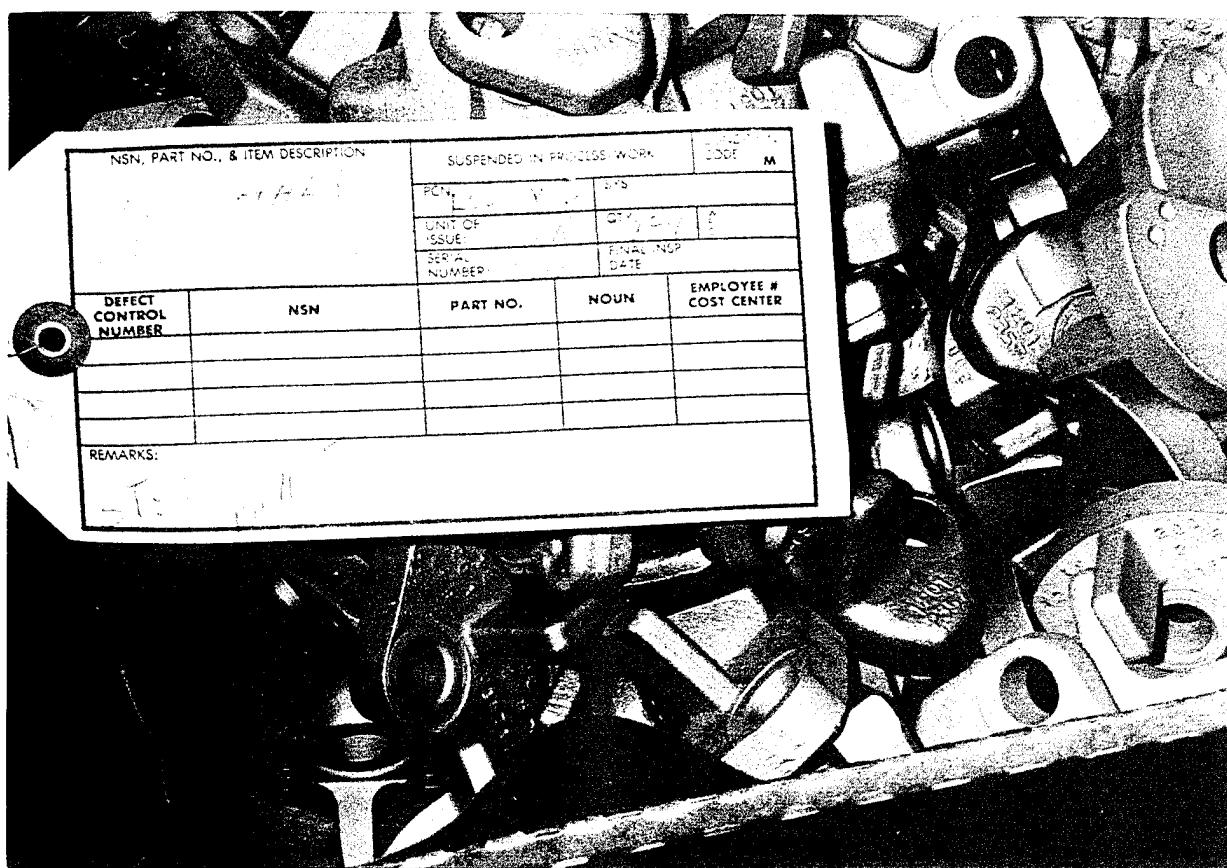
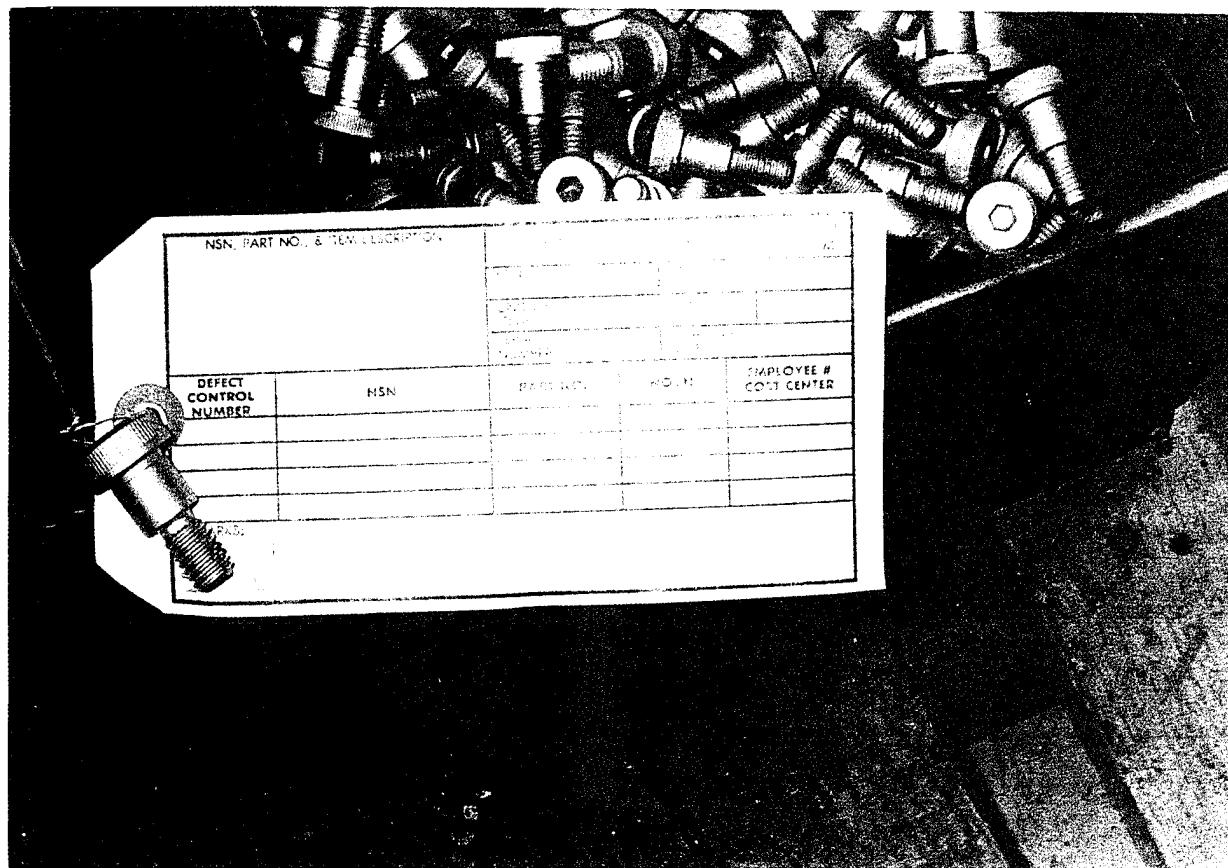


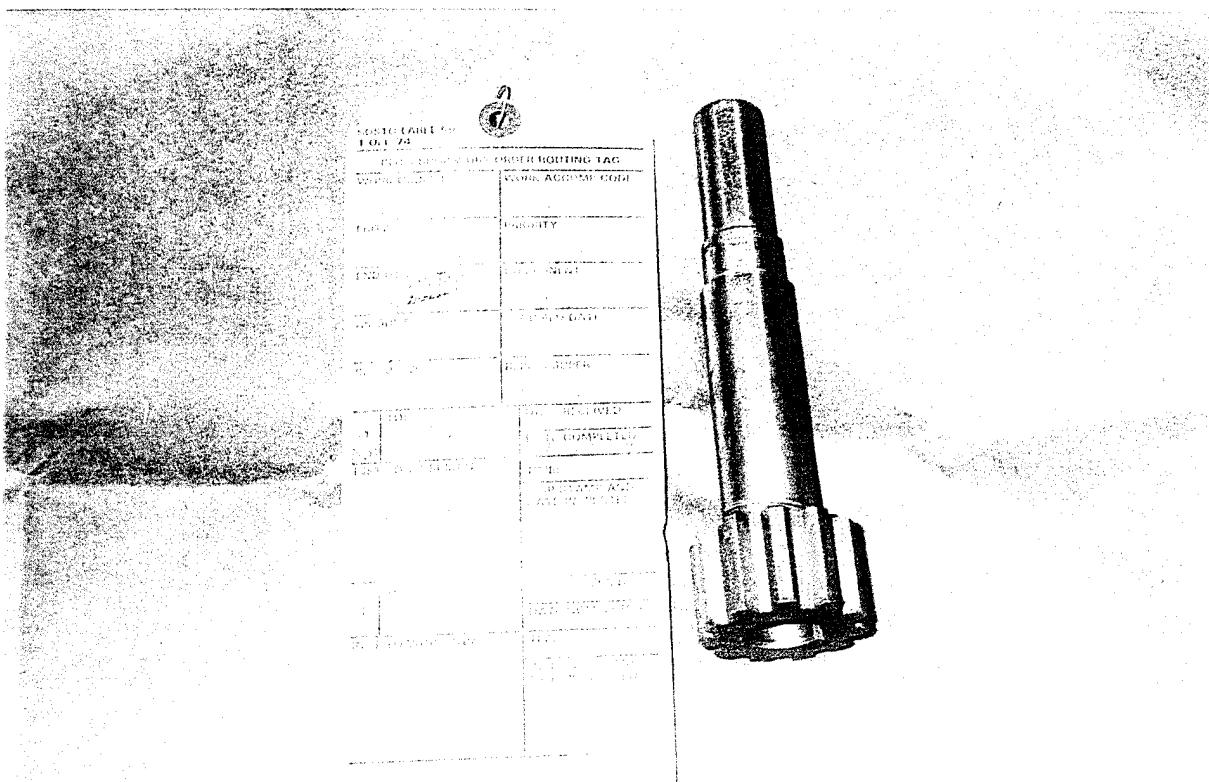
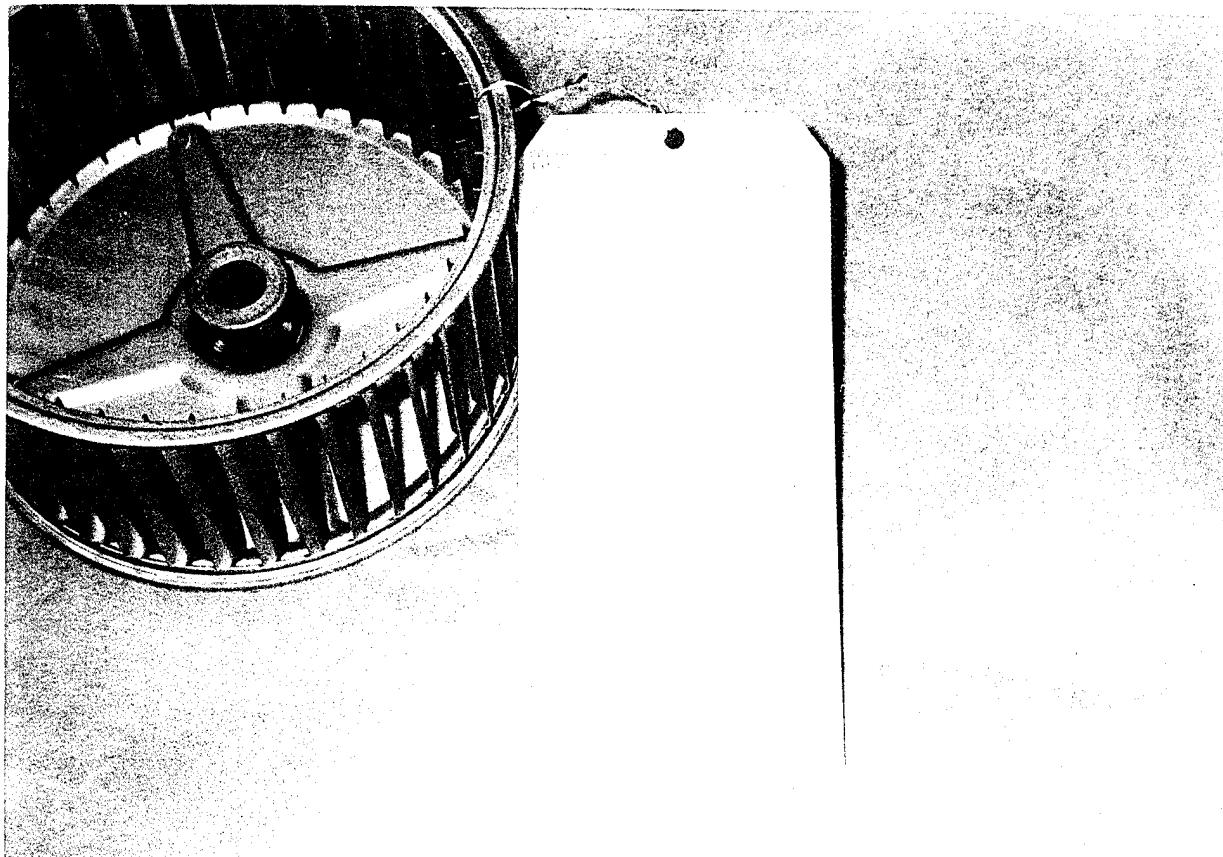


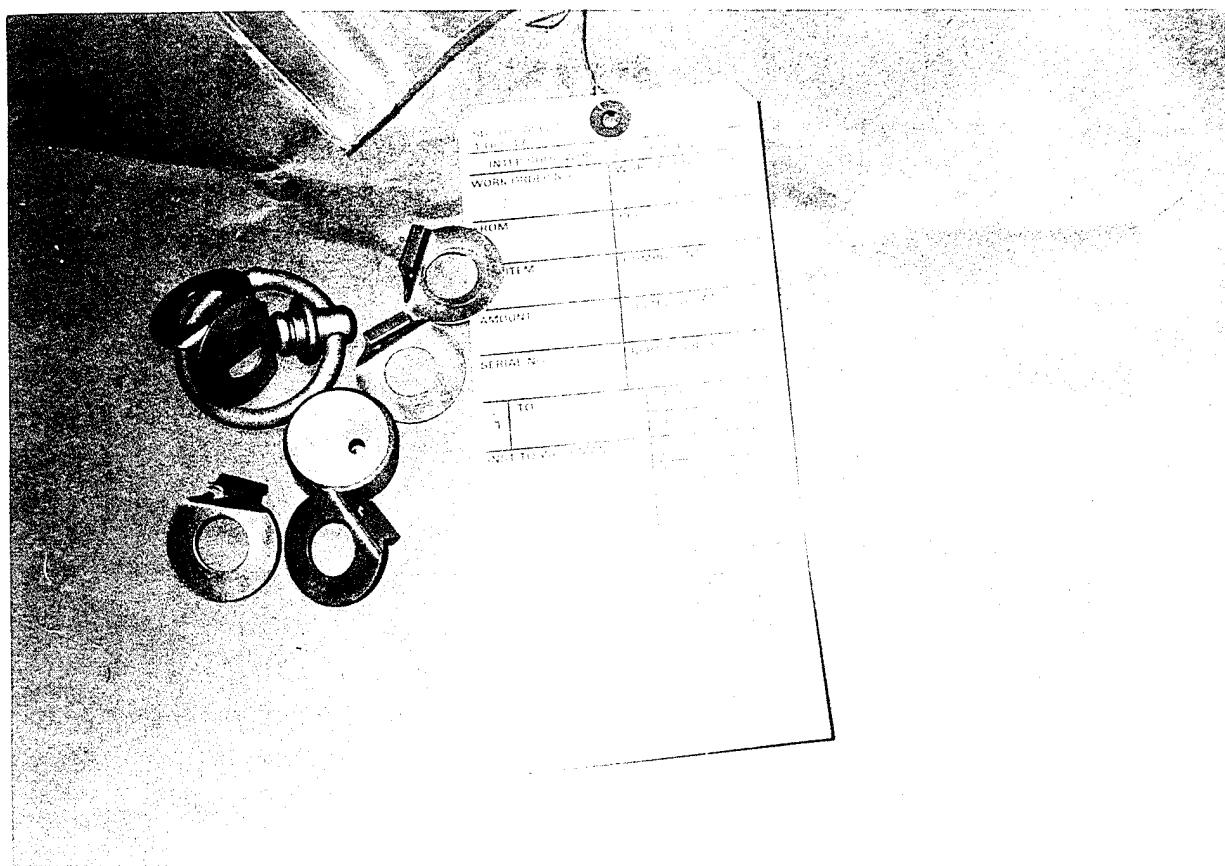
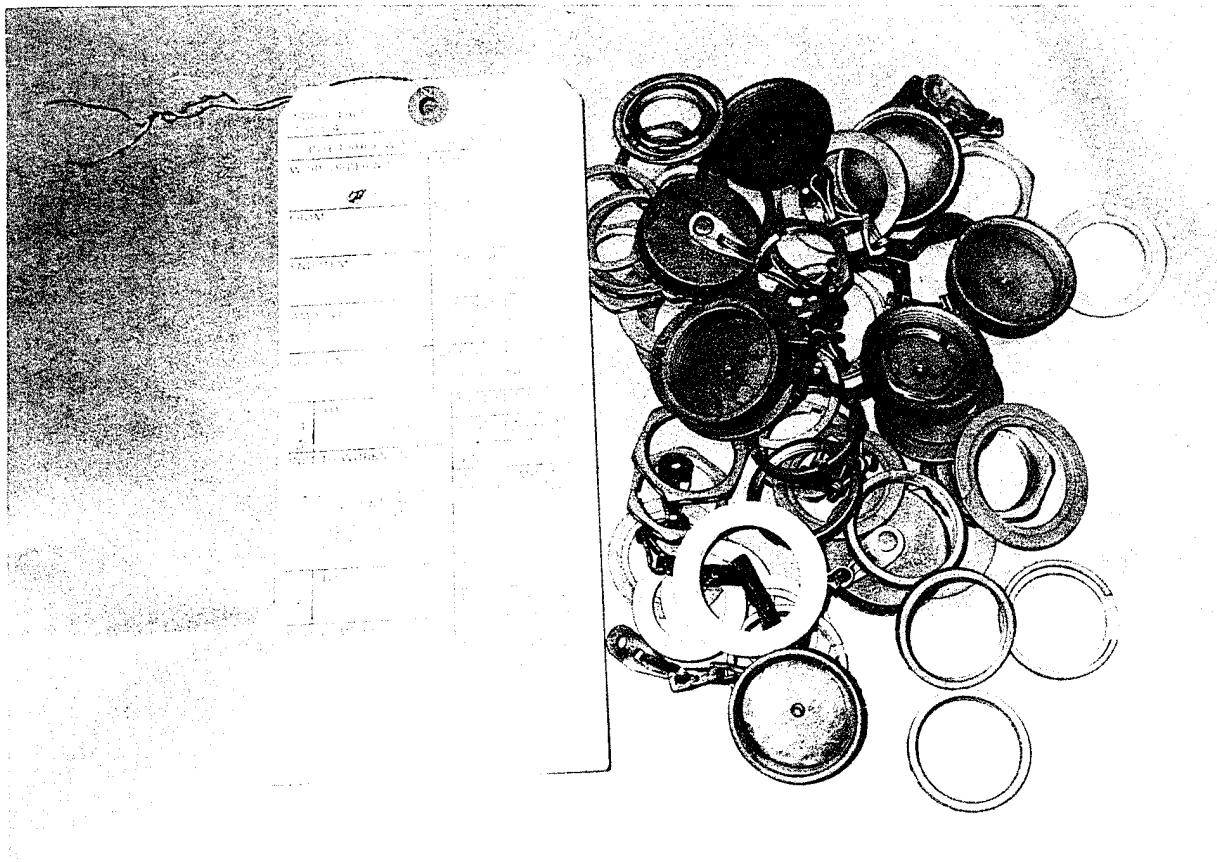


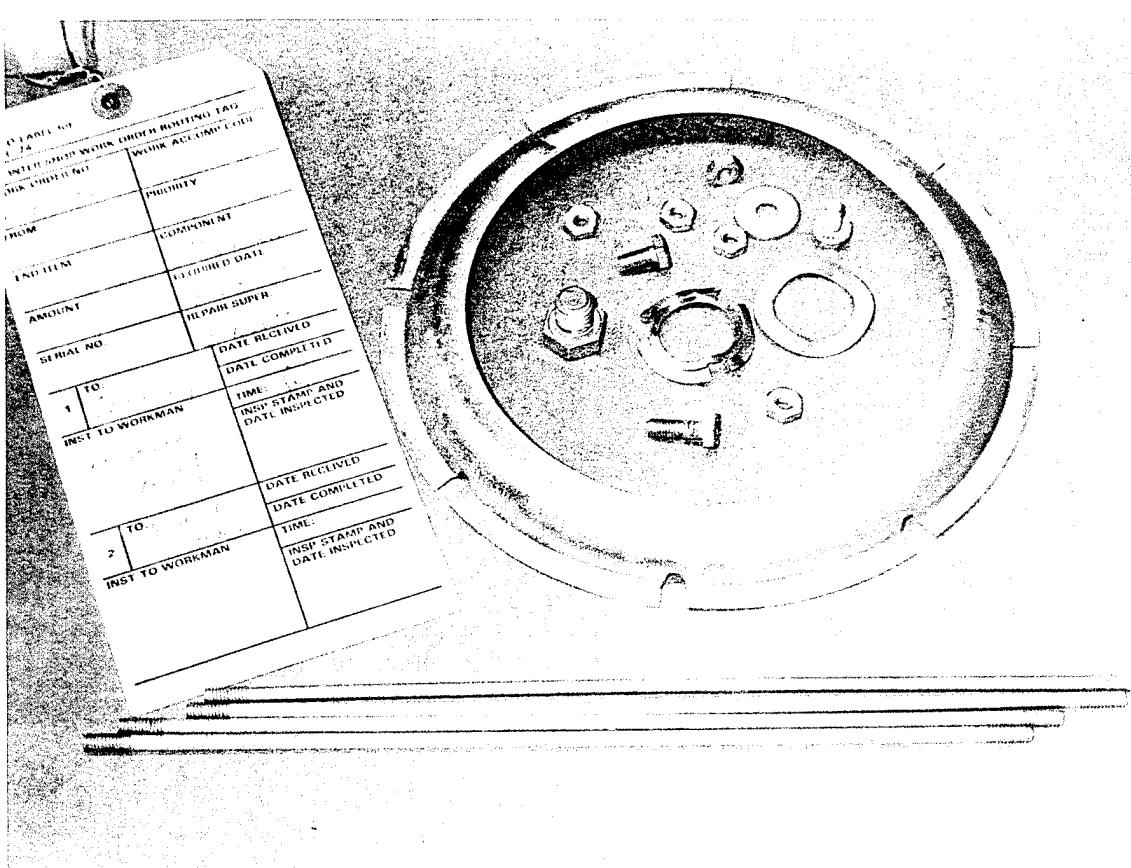
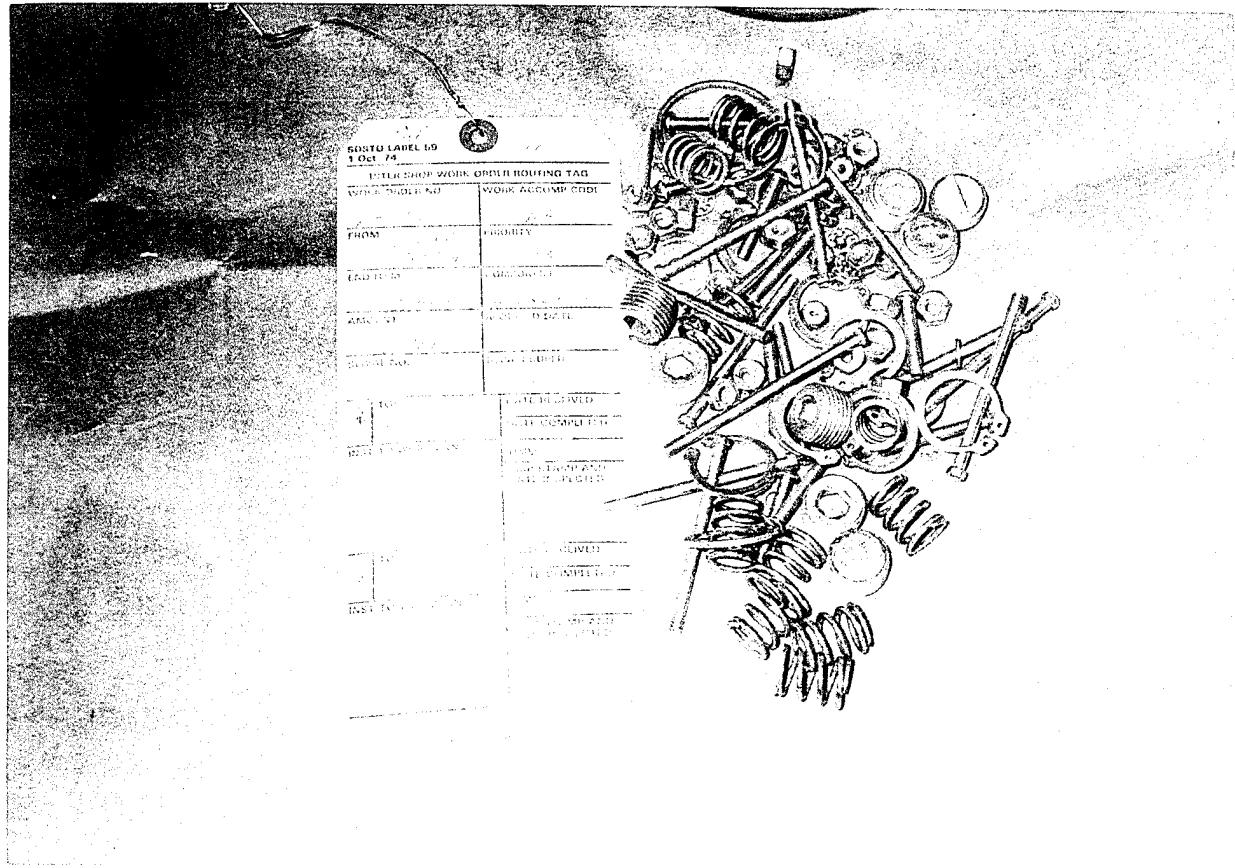
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END ITEM	COMPONENT
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1 CDA	12/20/70
SERIAL NO	REPAIR SUPER
64	C770
1 TO	DATE RECEIVED
1 LATAN'S	DATE COMPLETED
INST TO WORKMAN	TIME:
STK. 1414	INSP STAMP AND
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INST TO WORKMAN	TIME:
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	DATE INSPECTED

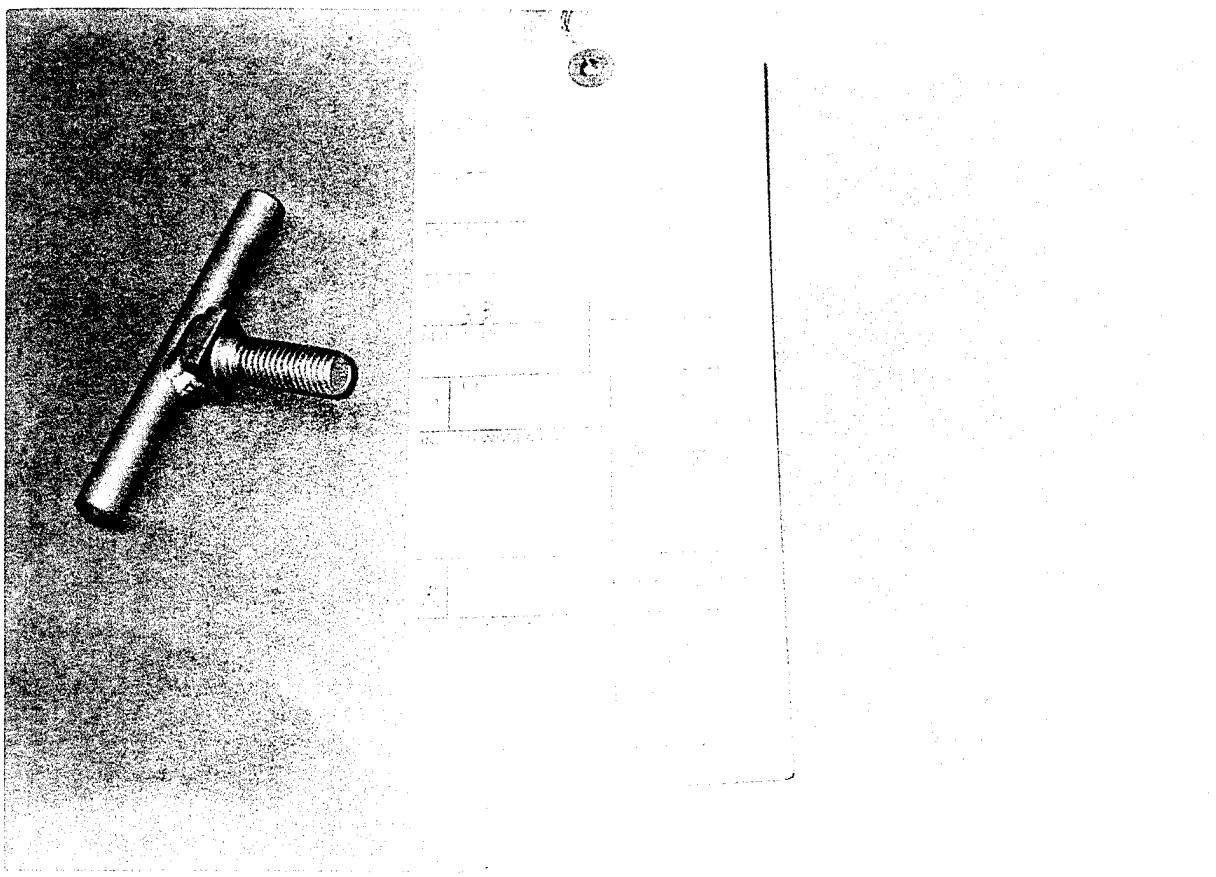
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FROM	PRIORITY
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64	C770
1 TO	DATE RECEIVED
1 LATAN'S	DATE COMPLETED
INST TO WORKMAN	TIME:
STK. 1414	INSP STAMP AND
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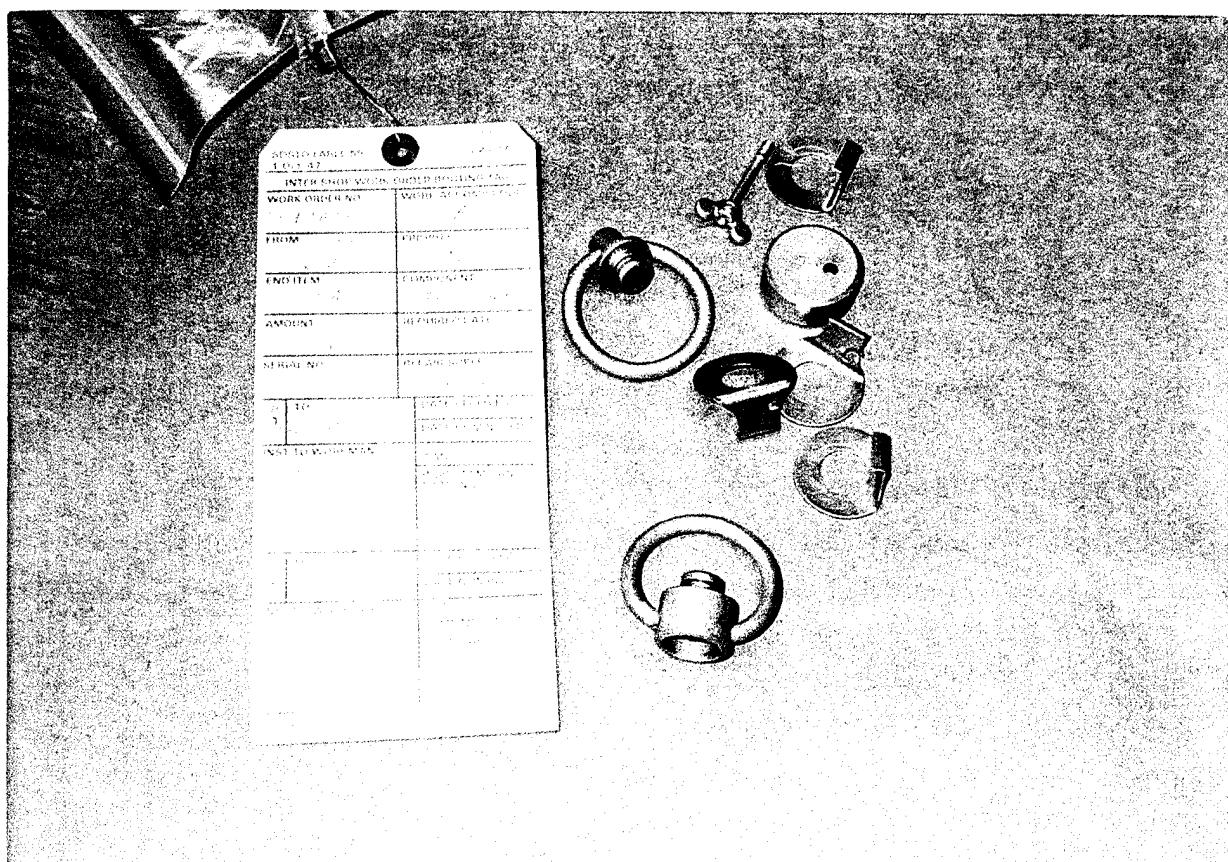
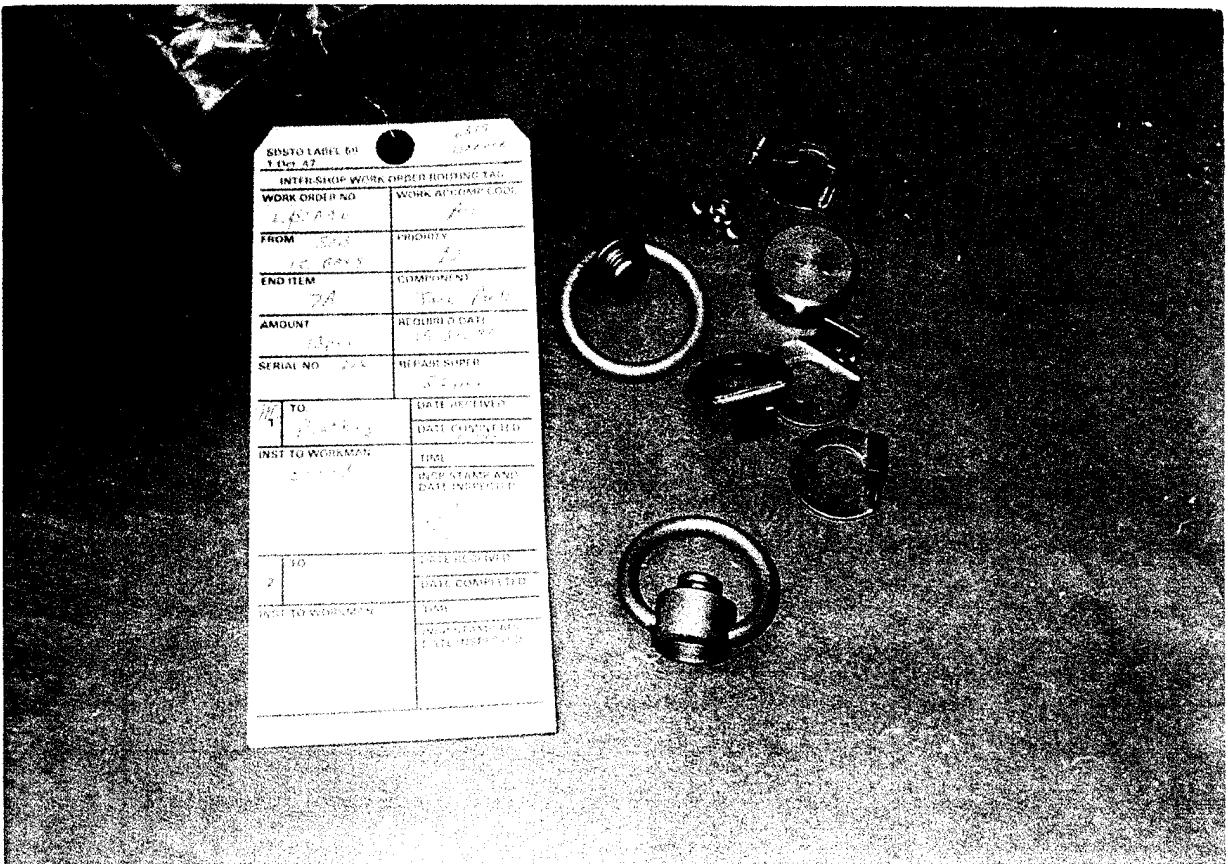












Appendix F

Bid Specification for Procurement of an AIVD System at TOAD

**BID SPECIFICATIONS FOR
ALUMINUM ION VAPOR DEPOSITION
AT TOBYHANNA ARMY DEPOT**

Prepared by

**IT Corporation
Cincinnati, Ohio**

**Contract No. DACA31-91-D-0074
Task Order No. 3
IT Project No. 322244**

**USAEC COTR
Mr. Edward G. Engbert**

**USAEC Project Engineer
Mr. James G. Heffinger, Jr.**

**U.S. Army Environmental Center
Environmental Technology Division
Aberdeen Proving Ground, Maryland**

**Revised
March 1995**

This bid specification document was prepared by IT Corporation under contract to the U.S. Army Environmental Center (Contract No. DACA31-91-D-0074). The format and content of this document are based on examples provided to IT by Tobyhanna Army Depot, Corpus Christi Army Depot, and Anniston Army Depot. The document was prepared in accordance with the examples provided to facilitate its review by and usefulness to depot personnel.

The views, opinions, and/or findings contained in this report should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other documentation.

The use of trade names in this report does not constitute an official endorsement or approval of the use of such commercial products. This report may not be cited for purposes of advertisement.

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1.0 SCOPE

1.1 Scope.

This specification provides the minimum requirements for the design, manufacture, performance, inspection, procurement, and installation of an ion vapor deposition system to be used for coating low-alloy steel, stainless steel, aluminum alloy, and titanium alloy parts with high-purity aluminum. This specification lists the minimum criteria and does not limit technological advances. This specification also includes provisions for technical manuals and personnel training in the theory of operation and maintenance for the equipment provided.

2.0 APPLICABLE DOCUMENTS

2.1 Government documents.

The following documents of the issue in effect on the date of the request for the proposal form a part of the specification to the extent specified herein:

SPECIFICATIONS

MILITARY:

- MIL-D-1000 - Drawings, Engineering and Associated List.
- MIL-M-7298 - Manuals, Commercial Off-the-Shelf.
- MIL-P-15024 - Plates, Tags, and Bands for Identification of Equipment.
- MIL-C-5541B - Chemical Conversion Coatings on Aluminum and Aluminum Alloys.
- MIL-C-83488C - Coating, Aluminum, Ion Vapor Deposited.

STANDARDS

FEDERAL:

- FED-STD-H28 - Screw Thread Standards for Federal Services.

MILITARY:

- MIL-STD-129 - Marking for Shipment and Storage.

OTHER GOVERNMENT AGENCY:

U.S. DEPARTMENT OF LABOR

OSHA 2206 - General Industry, OSHA Safety and Health Standards, 29 CFR 1910.

(Copies of specifications, standards, drawings, and other publications required by suppliers in connection with specified procurement functions should be obtained from the contracting agency or as directed by the contracting officer.)

2.2 Nongovernment documents.

The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated, the issue in effect on the date of the request for proposal shall apply.

STANDARDS

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

ASME - Boiler and Pressure Vessel Codes - 1989

(Application for copies should be addressed to: American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017.)

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM-D-3951 - Standard Practice for Commercial Packaging.

(Application for copies should be addressed to: American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.)

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA-250-85 - Enclosures for Electrical Equipment.

(Application for copies should be addressed to: National Electrical Manufacturers Association, 2101 L Street, NW, Suite 300, Washington, D.C. 20037.)

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA-70 - National Electrical Code

NFPA-79 - Electrical Standard for Industrial Machinery.

(Application for copies should be addressed to: National Fire Protection Association, 470 Atlantic Avenue, Boston, MA 02210.)

NATIONAL ASSOCIATION OF PLUMBING-HEATING-COOLING CONTRACTORS/AMERICAN SOCIETY OF PLUMBING ENGINEERS

National Standard Plumbing Code

(Application for copies should be addressed to: National Association of Plumbing-Heating-Cooling Contractors, P.O. Box 6808, Falls Church, VA 22040.)

2.3 Order of precedence.

In the event of conflict between the text of this specification and the references cited herein, the text of this specification shall take precedence. However, nothing in this specification shall supersede applicable laws and regulations unless a specific exemption has been obtained.

3.0 REQUIREMENTS

3.1 General information and coverage.

The ion vapor deposition machine described herein shall be capable of producing high-purity aluminum coatings in accordance with the requirements of MIL-C-83488C and MIL-C-5541C. The equipment shall be one of the manufacturer's current production models, new and unused, capable of performing its intended function in accordance with the operation and performance requirements specified herein. The equipment shall be complete so that when connected to the utilities specified, it can be used for any function for which it is designed and constructed.

3.1.1 Production model.

The equipment offered shall, on the date a proposal is submitted in response to this solicitation, have been designed, engineered, and previously produced. Products such as a prototype unit, a preproduction model, or a highly modified current model, for which major components have been redesigned, do not qualify as meeting this requirement.

3.2 Definition.

The equipment covered by this specification is described in terms of performance characteristics and design features. Any items not specifically mentioned herein that are essential for the proper installation and safe operation of the equipment shall be included. The equipment shall consist of the following principal components, attachments, and accessories necessary to meet the requirements specified herein.

Chamber
Pumping System
Parts Rack

Dual-Barrel Accessory
Air Transport Dollies
High-Voltage Power Supply
System Protective Features
Interlocks and Limit Switches
Aluminum Evaporators
Water Cooling System
Control Console
Spare Parts

3.3 Characteristics.

The equipment shall provide, as a minimum, the capabilities, characteristics, and performance specifications described herein.

3.3.1 Chamber.

3.3.1.1 Chamber size.

The ion vapor deposition chamber shall be a minimum of 6 ft in diameter and 12 ft long. The minimum area available for coating parts shall be approximately 5 ft by 10 ft.

3.3.1.2 Chamber construction.

The chamber shall be constructed of mild steel and be designed and constructed to comply with the ASME Boiler and Pressure Vessel Codes of 1989.

3.3.1.3 Chamber door.

The chamber shall have a full-diameter door hinged at one end through which parts will be loaded and the evaporation system serviced.

3.3.1.4 Chamber penetrations.

The chamber shall have, as a minimum, the following connections:

i. Chamber door sight port.

One 12-inch-diameter sight port shall be provided in the door of the chamber. A removable slotted plexiglass shield shall be provided inside the chamber to prevent aluminum buildup on the sight ports.

ii. Chamber sight port.

Two sight ports, 6 inches in diameter, shall be provided on the straight section of the chamber. Removable slotted plexiglass shields shall be provided inside the chamber to prevent aluminum buildup on the sight ports.

- iii. Evaporator electrode/cooling line pass-throughs.
One aluminum flanged port in the bottom of the chamber shall be provided for the evaporator electrode pass-throughs and cooling lines.
- iv. Vacuum gauge connections.
All required vacuum gauge connections shall be provided.
- v. Argon inlet port.
An argon inlet port shall be provided.
- vi. Backfill port.
A backfill port shall be provided to vent the chamber back to atmospheric pressure. A muffler shall be provided on the backfill port to reduce the noise level at the source to 84 dbA or less during venting.
- vii. Nitrogen inlet port.
A nitrogen inlet port shall be provided.
- viii. Liners.
Liners shall be mounted in sections inside the chamber wall. The liners shall be constructed to be easily removed for cleaning. Dimensions of individual liners shall not exceed 2 feet by 2 feet. Individual liners shall not exceed 40 lb in weight.

3.3.2 Pumping system.

At a minimum, the chamber shall have a pumping system consisting of a roughing pump, a mechanical pump, and a diffusion pump. The pumping system shall be capable of achieving a vacuum of 8.5×10^{-6} Torr within 30 minutes when the chamber is clean.

3.3.2.1 Cryopump.

A nominal 50-foot copper coil or equivalent plate coil shall be installed inside the coater and pass through the coater wall through a cryogenic pass-through. An external refrigeration unit shall be attached to the copper coil by an 8-foot transfer line. The cryopumping speed of the assembled system shall be rated at 70,000 liters/second for water vapor. The refrigeration unit shall not contain any ozone-depleting chemicals (ODCs).

3.3.2.2 Holding pump.

A 10-c.f.m. (285-lpm) holding pump shall be connected to the diffusion pump.

3.3.2.3 Vacuum valves (roughing and foreline).
Electropneumatic gate-type roughing and foreline valves shall be provided for the pumping system.

3.3.2.4 Holding pump valve.
An electropneumatic bellows-sealed holding pump valve shall be provided to control the holding pump.

3.3.2.5 High-vacuum valve.
A high-vacuum valve shall be provided for the diffusion pump. The valve shall be modulated to automatically control system pressure.

3.3.2.6 Pressure measurement.
All required pressure gauges shall be provided to monitor pressures in the chamber, roughing line, and foreline/holding line combination.

3.3.2.7 Pressure controller.
A pressure controller shall be provided to control the chamber pressure at any preset pressure between 1 and 5 μ . The controller shall maintain the preset pressure within $\pm\frac{1}{2}$ μ . The pressure controller shall have a digital readout mounted on the control console.

3.3.2.8 Chamber pumpdown.
The chamber pumping system shall be capable of pumping down to 8.5×10^{-6} Torr within 30 minutes with a dry, clean chamber.

3.3.3 Parts rack.
Two removable parts racks shall be provided for hook suspension of parts to be coated. One of the two racks provided shall be specially designed to provide a minimum working space of 24 inches between the parts rack and the movement of the aluminum evaporation system. This specially designed rack shall accommodate parts of up to 24 inches in length. Each rack shall be capable of supporting a load of 1200 pounds for any single part. The parts racks shall be capable of interfacing with both the vacuum chamber and the parts dolly to facilitate rapid transfer of parts into and out of the vacuum chamber. The parts rack shall be equipped with eyehooks to support the hangers holding the parts to be coated. The eye hooks shall be capable of supporting a load of 1200 pounds. The eyehooks shall be centralized over the openings in the parts rack and, therefore, minimize short-circuits resulting from parts placed off-center on the parts rack.

3.3.4 Dual-barrel accessory.
Several of the parts coated at the Tobyhanna Army Depot are small parts typically coated in barrel coaters. Segregation of the parts in small groups is

important to permit correct tracking and routing of parts. A dual-barrel accessory for rotational tumbling of small parts shall consist of the following:

3.3.4.1 Barrels.

The barrel accessory shall consist of a dual barrel of stainless steel 14 inches in diameter by 48 inches long. End closure assemblies shall be machined, welded, and bolted to constrain parts to the inside of the barrels. Provisions shall be incorporated to permit loading/unloading of parts. If possible, the barrel shall be compartmentalized to permit segregation of smaller quantities of parts.

3.3.4.2 Drive mechanism.

The dual-barrel drive mechanism shall consist of a drive chain, mating sprockets, shafts, bearings, and universals that adapt to a rotary pass-through in the chamber wall. A variable-speed motor drive shall be located external to the chamber.

3.3.4.3 High-voltage wiper.

A metal wiper-type contact shall be provided for applying high voltage to the barrels.

3.3.4.4 Assembly construction.

The dual-barrel accessory shall be designed for installation in a standard 6-ft-diameter by 12-ft-long ion vapor deposition chamber and utilize the same chamber rails used to support other parts racks. The dual-barrel accessory shall include an air-ride transport dolly.

3.3.4.5 Outer shield.

A welded semicylindrical stainless steel outer shield shall be provided to constrain the glow discharge. The shield shall be easily removable for cleaning in a caustic tank with maximum dimensions of 2 feet wide by 2 feet long.

3.3.5 Air-ride transport dolly.

Air-ride transport dollies shall be provided to transport and support each parts rack, including the stationary part holding rack and dual-barrel assembly.

3.3.6 High-voltage power supply.

A high-voltage power supply to be used for glow discharge cleaning of the parts shall be provided. The controls for this power supply shall be located in the control console. The high-voltage supply shall have a rating of 2 kV DC, 2.5 amps. A timer located in the control console shall be provided to monitor the time duration for glow discharge cleaning.

3.3.7 System protective features.

3.3.7.1 Power failure.

Should a power failure occur, the ion vapor deposition system shall be protected from damage; i.e., the system shall be fail-safe. At a minimum, the following protective safeguards shall be provided:

- i. Isolate the vacuum vessel from the pumping system.
- ii. Isolate the diffusion pump from the mechanical pump.
- iii. Vent the mechanical pump to atmospheric pressure.
- iv. Open all electrical circuits.

3.3.7.2 Diffusion pump thermal switch.

A thermal switch shall be provided to shut off the diffusion pump should the cooling water fail.

3.3.7.3 Diffusion pump coolant flow.

A flow switch shall be provided to shut off power to the diffusion pump heater should the coolant flow be stopped or interrupted.

3.3.7.4 High foreline pressure cutoff.

The diffusion pump heater shall be cut off when the foreline pressure, as measured by the foreline vacuum gauge, rises above a predetermined level. This shall prevent excessive backstreaming.

3.3.7.5 Voltage spikes or voltage dips.

The power supply at Tobyhanna may be subject to voltage spikes or voltage dips. All components of the ion vapor deposition system shall be designed to provide protection against such variances in the power supply.

3.3.8 Interlocks and limit switches.

All necessary controls shall be interlocked to provide maximum safety for personnel and equipment.

3.3.9 Aluminum evaporators.

The aluminum evaporation source shall consist of the following:

3.3.9.1 Boats.

Seven intermetallic composite resistance-heated boats shall be mounted in a single row. The boats shall be electrically isolated from each other. It shall be possible to individually turn each boat off or on as

well as control the power to each boat. Seven additional boats shall also be provided as spares.

3.3.9.2 Boat clamps.

All required boat clamps shall be designed to expand as the boats are heated to allow for thermal expansion and to reduce boat breakage.

3.3.9.3 Water-cooled electrodes.

The electrodes shall be water cooled.

3.3.9.4 Aluminum wire feed mechanisms.

Individual aluminum wire feed mechanisms shall be provided for each boat. They shall be electrically isolated from each other. It shall be possible to individually turn each wire feed mechanism off or on as well as control the feed rate of each wire feed.

3.3.9.5 Aluminum wire supply spools.

Separate wire supply spools shall be provided for each boat. The holders shall be designed to use standard-size prewound spools. Seven additional spools of wire shall be provided as spares.

3.3.9.6 Boat shields.

Shields shall be installed above boats to prevent buildup on the sides.

3.3.9.7 Boat carriage.

Carriage shall move while boats are heating to prevent parts from overheating.

3.3.10 Water-cooling system.

3.3.10.1 General.

A water-cooling manifold shall be provided for supplying cooling water to the boats, roughing pump/blower, diffusion pump, and other subsystems requiring cooling water. The cooling water system shall be closed loop with no discharges and shall incorporate the means to maintain the required water temperature. The cooling water system shall not use any ozone-depleting chemicals (ODCs).

3.3.10.2 Convection cooling system.

A nitrogen gas cooling system shall be provided to allow for the coating of temperature-sensitive parts. The system shall consist of the following:

- i. One manifold down one side of the chamber below the parts rack with evenly spaced orifices to direct the cooling gas onto the parts.
- ii. A pressure- and gas-flow-regulating system to maintain the chamber below atmospheric pressure during the cooling cycle.
- iii. A special door clamp to prevent inadvertent pressurization of the chamber in case of malfunction of the cooling system.

3.3.10.3 Inadequate water-flow protection.

The ion vapor deposition system shall be shut down if the flow of cooling water is inadequate for system operation. Subsystem water-flow failure shall be indicated by the subsystem on/off lamps located on the control console.

3.3.11 Control console.

The operation of the ion vapor deposition system shall be controlled by a computer controller located in a free-standing control console.

3.3.11.1 Computer controller.

The computer controller shall, at a minimum, control the following system functions:

- i. Automatic valve controls.
Automatic valve controls shall be provided for manual or automatic operation of the pumping system. The automatic valve controls shall permit the chamber to automatically pump down to a specific preset pressure from atmospheric pressure. The computer controller shall permit an auto startup sequence that shall initiate pump down at a preset time (e.g., each morning prior to personnel arriving on site).
- ii. The controls shall provide for argon plasma cleaning of the parts and nitrogen cooling for temperature-sensitive parts.
- iii. Thermocouple gauges.
Two thermocouple gauges shall be provided to monitor the pressure in the system. One gauge shall be located in the foreline/holding line. The computer controller shall be capable of receiving and displaying outputs from the thermocouple gauges. Additional meter readouts shall be provided on the control console.

iv. Ionization gauge.

One ionization gauge shall be provided to monitor the chamber pressure below the range of the thermocouple gauges. The computer controller shall be capable of receiving and displaying the output of the ionization gauge. An additional meter readout shall be provided on the control console.

v. Boat rack drive controls.

The computer controller shall be capable of controlling the speed and number of passes of the boat rack drive.

vi. Aluminum evaporation source power control/monitor.

The computer controller shall be capable of controlling the power input to each boat individually, and shall be capable of turning each boat off or on independently. Additional manual controls for the evaporation sources shall be provided in the control console. One ammeter for each boat shall be provided to monitor the boat condition during plating.

vii. Aluminum wire feed controls.

The computer controller shall be capable of controlling the rate of wire feed to each boat individually, and shall be capable of turning each wire feed off or on independently.

3.3.11.2 Hardware.

Minimum hardware for the computer controller shall include the following:

- i. The computer shall be an Intel 486, or 66-MHz equivalent, system.
- ii. Input to the controller shall be by means of a standard IBM, or equivalent, keyboard.
- iii. The video monitor shall be color, 14-inch minimum, SVGA.
- iv. A wide-carriage 24-pin, 360 x 360 dots per inch (dpi) dot-matrix printer shall be provided to print output from the computer controller.
- v. A minimum 9600-baud modem shall be provided to permit communications between the computer controller and the contractor's office for downloading diagnostic data from the controller.

3.3.11.3 Control program.

The computer shall be programmed by the contractor to perform all required control functions. The controller shall be capable of storing and retrieving sets of system operating conditions corresponding to different coating types. A backup copy of the control program software shall be provided on 3½-inch floppy disks to permit reloading the system software, if necessary.

3.3.11.4 Remote diagnostics.

The computer controller shall incorporate the hardware and software necessary to permit the contractor's office to remotely download diagnostic data from the controller at the request of the Army Depot.

3.3.12 Electrical requirements.

3.3.12.1 Power cabinet.

The ion vapor deposition chamber shall be designed to use 480-volt, three-phase, 60-Hz power. A main power panel, NEMA Type 12 enclosure, with panel door interlock, shall be provided with a main 480-volt, three-phase, 60-Hz circuit breaker, with an interchangeable trip unit and a short-circuit interrupting rating of 30,000 amps RMS. Delta connection for three-phase windings is standard at the facility.

The line side of the circuit breaker shall be provided with minimum double-barrel lugs. All power requirements of the ion vapor deposition system shall be derived from this single source. All interconnecting wiring, conduit, etc., shall be contractor supplied.

3.3.12.2 Equipment protection.

Short-circuit protection shall be provided for auxiliary controls, instruments, relays, sensing devices, etc. All electrical motors of ¼ horsepower and larger shall be provided with short-voltage, under-voltage, and thermal-trip-overload protection. Motor sizes shall be such that the driven load does not exceed the continuous-duty rating of the motor.

3.3.12.3 Electric motors.

All motors shall be ball- or roller-bearing type and rated for continuous duty. Each AC motor used in the ion vapor deposition system shall be dual voltage and suitable for its application, and shall meet the requirements for either a drip-proof or totally enclosed fan-cooled enclosure. The motor enclosures shall conform to the NEMA standards. Electric motors 0.75 horsepower and larger shall be of three-phase construction. Where standard "V" belt drives are used, they shall be sized to transmit 150 percent of developed horsepower.

3.3.12.4 Grounding.

The equipment provided shall have a single-point grounding stud 5/8 inch in diameter or larger. The resistance between the grounding stud and all other exposed metallic parts shall not exceed 2.0 ohms.

3.3.12.5 Electrical equipment.

All electrical components, including motors, starters, relays, switches, and wiring, shall conform to and be located in accordance with NFPA 70 and 79, and all applicable OSHA and NEMA standards.

3.3.12.6 Identification.

All electrical components and wiring shall be permanently identified. Complete and accurate wiring and schematic diagrams shall be supplied depicting the same.

3.3.12.7 Control cabinet.

All instruments and controls shall be front-panel-mounted in a single-console, NEMA Type-12 enclosure with panel door interlocks, and shall be functionally grouped, permanently identified, and conveniently located for single-operator control. Control circuit voltage shall be 120 volts, 60 Hz.

3.3.13 Equipment anchorage and supports.

The ion vapor deposition chamber and its related items of support equipment, whether mechanical or electrical, shall be securely anchored and braced.

3.3.14 Reliability.

The reliability of the machine shall be no less than 4000 hours Mean Time Between Failures (MTBF). The machine reliability shall be 99.7 percent. These requirements can be validated by the contractor by a theoretical study or by citing comparability to similar systems presently in use.

3.3.15 Maintainability.

The machine design and configuration shall permit direct access for adjustment/testing/replacement of components. Removal and replacement of machine components shall require the removal of the minimum number of other machine components.

3.3.15.1 Spare parts.

The contractor shall include in the proposal the following spare parts:

- i. Initial change of diffusion pump oil.
- ii. Initial change of roughing pump oil.

- iii. Initial change of holding pump oil.
- iv. Seven complete sets of intermetallic boats.
- v. Fourteen spools of aluminum wire.
- vi. Two thermocouple gauges.
- vii. One ionization gauge.
- viii. Seven wire-feed gear sets.
- ix. One electropneumatic-gate-type valve (ref: paragraph 3.3.2.3).
- x. One complete change of fuses

3.3.16 Environmental conditions.

The equipment shall be designed and constructed such that, under the operating, service, transportation, and storage conditions described herein, the equipment shall not emit materials hazardous to the ecological system as prescribed by federal, state, or local statutes in effect at the time of installation.

3.4 Design and construction.

The machine shall be constructed of parts that are new or reclaimed, without defects, and free of repairs. The equipment structure shall be capable of withstanding all forces encountered during operation of the machine to its maximum rating and capacity without permanent distortion.

3.4.1 Materials.

3.4.1.1 Castings and forgings.

All castings and forgings shall be free of defects, scale, and mismatching. No process, such as peening, plugging, or filling with solder or paste, shall be used for reclaiming any defective parts.

3.4.1.2 Welding, brazing, or soldering.

Welding, brazing, or soldering shall be employed only where specified in the original design. None of these operations shall be employed as a repair measure for any defective part.

3.4.1.3 Fastening devices.

All screws, pins, bolts, and other fasteners shall be installed in a manner that prevents change of tightness. Those subject to removal or adjustment shall not be swaged, peened, staked, or otherwise permanently installed. All fastening devices shall be tightened to torque limits as established by the manufacturer's standard for tightening to preclude loosening by normal operation or vibration.

3.4.1.4 Painting.

The machine and its associated equipment shall be properly painted prior to shipment. Painting may be the manufacturer's standard practice provided it results in a highly wear-resistant finish that guarantees continued protection to the surfaces covered against the environment under all service conditions. Prior to finish painting, surfaces shall be properly cleaned, prepared, and primed. Poor adhesion of paint shall be construed as evidence of improper preparation of surfaces. Items such as fabrics, plastics, rubber, working parts, and other surfaces not normally painted in good commercial practice shall not be painted. Unless otherwise specified, the color scheme may be the manufacturer's standard colors provided it results in a uniform finish to all painted surfaces.

3.4.2 Nameplates and product markings.

All plates, tags, and bands for identification shall be in accordance with MIL-P-15024. All words on indicating plates and on instruction plates shall be in the English language. Words shall be engraved, etched, embossed, or stamped in bold-face letters on a contrasting background.

3.4.2.1 Nameplate.

A corrosion-resistant metal nameplate shall be securely attached to the machine. The nameplate shall contain the information listed below. The captions listed may be shortened or abbreviated, provided the entry for each caption is clear as to its identity.

Nomenclature
Manufacturer's name
Manufacturer's address
Manufacturer's model designation
Manufacturer's serial number
Size
Power input (volts, total amps, phase, frequency)
Contract number
Date of manufacture
Country of manufacture

3.4.2.2 Lubrication plate.

A lubrication plate shall be permanently and securely attached to the machine. The plate shall contain the following information:

Points of lubricant service
Service interval
Type of lubricant
Viscosity
Federal or Military Specification (if any)

3.4.3 Workmanship.

Workmanship of the machine and accessories shall be comparable in quality to that of the manufacturer's commercial equipment. All surfaces shall be cleaned and free of sand, dirt, fins, sprues, flash, scale, flux, and other harmful or extraneous materials. All edges shall be either rounded or beveled.

3.4.4 Interchangeability.

All replacement parts shall be designed and constructed to definite standards, tolerances, and values in order that any such part of this equipment furnished under the specification shall be replaceable, interchangeable, or adjustable without modification to the equipment. All replacement parts, when practicable, shall be permanently and legibly marked with the manufacturer's part number.

3.4.4.1 Threads.

All threaded parts used on the machine and its related attachments and accessories shall conform to FED-STD-H28.

3.4.4.2 Measurement systems.

Either U.S. Customary System of Units (US) or the International System of Units (SI) may be used in the design and construction. In this specification, all measurements, dimensions, sizes, and capacities are given in US. These measurements may be converted to SI through the use of the conversion factors and methods specified in ANSI Z210.1.

3.4.5 Safety.

Covers, guards, or other safety devices shall be provided for all parts of the machine that present safety hazards. The safety devices shall not interfere with operation of the equipment. The safety devices shall prevent unintentional contact with the guarded part, and shall be removable to facilitate inspection, maintenance, and repair of the parts. All machine parts, components, mechanisms, and assemblies furnished on the machine, whether or not specifically required herein, shall comply with the requirements of OSHA 2206 that are applicable to the machine itself. Additional safety and health requirements shall be as specified in other paragraphs of this specification.

Material Safety Data Sheets (MSDS) shall be provided for all hazardous materials (i.e., lubricants, oils, etc.).

3.4.6 Human engineering.

All operating controls shall be located convenient to the operator at his normal work station. The machine shall be designed and manufactured to minimize the possibility of human error and to ensure human/machine compatibility.

3.5 Documentation.

Technical manuals shall be developed in accordance with MIL-M-7298, Commercial Off-the-Shelf Manuals. Diagrammatic, assembly, detail, control, and installation drawings shall be in accordance with DOD-D-1000, Drawings, Engineering, and Associated List. Technical data supplied shall be written in the English language and comply with the requirements of DD Form 1423.

The following technical data shall be provided with the equipment: operator's manuals, maintenance manuals, calibration specifications/procedures, catalogs, and spare parts lists. Maintenance manuals shall include electrical, hydraulic, and pneumatic schematics, as applicable, parts lists, trouble-shooting procedures, preventive maintenance requirements, lubrication schedule, etc. Schematics shall show and identify all parts down to and including components on circuit boards. Catalogs shall fully describe all optional tooling, fixtures, and attachments available for the equipment being furnished. The recommended spare parts lists shall be complete with quantities required, prices, and normal delivery time for the items. In addition, any other technical data normally furnished with the equipment shall be provided.

3.6 Logistics.

3.6.1 Standard equipment.

All equipment, parts, and accessories necessary to meet the requirements of this specification shall be considered as standard equipment and shall be included in the proposal.

3.6.2 Spare parts list.

The offeror shall provide with his proposal a list of spare/repair parts recommended for the first year's maintenance of the same or similar equipment. The list shall include nomenclature of the part, manufacturer, unit cost, and delivery time for each part.

3.6.3 Installation.

3.6.3.1 Installation engineering plan.

Within 90 days after the award of a contract, the contractor shall provide a complete installation engineering plan to the Tobyhanna Army Depot. The installation engineering plan shall include a

complete set of drawings and detailed instructions on the installation requirements and the required electrical circuit amperage.

3.6.3.2 Installation coordination.

Installation of the system is to be complete and equipment operational within 60 calendar days after work begins. The contractor shall coordinate the proposed installation schedule with the Tobyhanna Army Depot within 90 days after the award of a contract to afford it the opportunity to prepare the installation site and provide the required utilities. The installation schedule shall be subject to approval by the Tobyhanna Army Depot. Approval of the installation schedule shall not relieve the contractor of performance to meet the schedule requirements for installation and operation of the system.

3.6.3.3 Contractor responsibilities.

The contractor shall be responsible for installing the ion vapor deposition system. The contractor shall provide all material and labor required to furnish a complete and operational system as specified herein.

i. Materials and labor.

The contractor shall provide all materials, moving equipment, piping, interconnecting hoses, cables, disconnects, tools, labor, and field supervision necessary to provide a completely operational system capable of meeting the requirements of Sections 3, 4, and 5 of this specification.

ii. Field supervisor.

The contractor shall provide a field supervisor to direct the installation and testing of the ion vapor deposition system. The field supervisor shall have full authority to implement his field decisions in an expeditious manner. All work shall be accomplished when the field supervisor is not in the immediate work area. The field supervisor's name shall be made known to the Tobyhanna Army Depot prior to the start of installation.

iii. Working conditions.

The area surrounding the installation site will be occupied with ongoing shop operations. The contractor shall comply with the regulations, including safety and security clearance restrictions, governing operations on the premises and shall administer the contract in a manner that does not unreasonably interrupt or interfere with the depots' normal business routine. The contractor shall take the necessary precautions to prevent dust and other airborne contaminants from affecting the

surrounding area. Work performed outside the normal working hours of the depot shall be done only with written approval and at no additional cost to the Government. Throughout the work process, the contractor shall confine his apparatus, storage of materials, and operation of his personnel within reasonable limits as specified by the depot. The contractor shall be responsible for damage to Army property, including, but not limited to, other machines, building structures, and utilities.

iv. Structural steel.

The contractor shall accurately set, plumb, and field connect with sufficient bolts and/or weld all structural steel required to make the installed equipment permanent.

v. Mechanical installation.

The contractor shall provide all labor and material to move, locate, set level, align, lubricate, and make ready to operate the equipment specified herein. All machinery shall be installed to original manufacturer's tolerances.

NOTE: The ion vapor deposition system shall be installed in Building 1B, Bay 1. The floor loading in this area shall not exceed 1000 pounds per square foot.

vi. Electrical installation.

The contractor shall furnish all labor and material required for complete installation and connection of all electrical equipment supplied. Installation shall include all power, control, and interconnect wiring installed in conduit. Installation shall conform to all local codes, NFPA 70 and 79, and NESC (ANSI C2-1984). The contractor shall furnish all circuit breaker bus duct plug-in devices, disconnect switches, circuit breakers for panel boards, or other devices necessary to obtain the required electric service. All materials used in the installation shall conform to applicable National Electrical Manufacturers Association (NEMA) and Underwriter Laboratories (UL) listings. Workmanship shall be in accordance with standard commercial practice. Runs shall be installed perpendicular and parallel to existing facilities and the equipment being installed. When equipment is installed near existing power lines, equipment shall be located for proper clearances in accordance with ANSI C2. New equipment shall not be connected to Government power without prior approval of the Contracting Officer. No high-voltage work will be

accomplished without prior approval of the Contracting Officer. All connections to Government power and all high-voltage work shall be performed in the presence of a Government employee qualified to do electrical work.

vii. Plumbing.

All plumbing work shall comply with National Association of Plumbing-Heating-Cooling Contractors/American Society of Plumbing Engineers (NAPHCC/ASPE) Publication - National Standard Plumbing Code. All materials used in the installation of the equipment shall conform to industry standards and shall be compatible with and shall meet the performance requirements of the equipment being installed. Workmanship shall be in accordance with standard commercial practice. Runs shall be installed perpendicular and parallel with existing facilities and the equipment being installed. Bypasses shall not be installed at steam reducing stations. All heating coils shall be trapped independently. Unless otherwise specified, steam and condensate piping shall be insulated with 1½-inch-thick calcium silicate with aluminum cover for outside lines and 1½-inch-thick fiberglass with all service jackets for interior lines unless subjected to water or vapor.

viii. Coordination of trades.

The contractor shall be responsible for coordinating the trade workers who will install the equipment.

ix. Instructions for installation.

Four copies of the instructions for installation shall be provided as specified on DD Form 1423. The government will use these instructions to review utility and space requirements of the proposed equipment. Within 30 days after date of contract, the contractor shall provide the Tobyhanna Army Depot with all information necessary for installation of the machine. This installation manual is to include, but not be limited to, the following:

- a. Floor plan drawing of the machine and major machine components showing floor space required.
- b. Space required around the machine after installation for maintenance purposes.
- c. Maximum overall length, width, and height dimensions.

- d. Approximate location of utility connections on the machine.
- e. All utility requirements including electrical, air, water, steam, drains, etc. Include amps, gpm, etc.
- f. Minimum doorway opening required to bring equipment into the building.
- g. Industrial waste disposal requirement, if any.
- h. Ventilation requirements, if any.
- i. Approximate weight of the equipment.

x. Utilities.

The Government will provide utilities within 20 feet of the equipment installation site. The capacities of the utilities (wire sizes, pipe sizes, etc.) will be based on information supplied by the contractor under Instructions for Installation noted above. Government-provided utilities at the job site are limited to the following:

a. Electrical.

The Government will run electrical lines and tie them into the contractor-furnished and -installed main disconnect. The Government will furnish only one voltage to the site.

b. Plumbing.

The Government will run pipe within 20 feet of the installation site. Nominal plant pressures supplied to the site will approximately be as follows:

Air	100 psi
Water	75 psi

c. Phone line.

The Government will provide one telephone line for installation of the modem for remote diagnostics. The phone line will have the capability of receiving and initiating local and long-distance calls.

d. Drainage and waste.

Unless otherwise specified in the contract solicitation, the contractor shall place drain lines and tie them into existing sanitary, storm, or industrial waste lines as required.

xii. Verification of installation.

After installation is completed, a qualified manufacturer's representative shall verify proper installation of the equipment in accordance with the manufacturer's instructions/specifications. Upon verification of the installation, the representative(s) shall demonstrate the operation and performance of the equipment. The equipment shall be operated at its full capacity for a period of time sufficient to verify proper operation of the equipment and its related accessories.

xiii. Site visit.

Prospective bidders are encouraged to visually inspect the installation site prior to bidding on the ion vapor deposition system. A site visit can be arranged by calling the contract specialist anytime between the issuance of the RFP and one week prior to the closing date.

3.7 Training.

The contractor's office shall include arrangements for the training of receiving activity personnel in electrical and electronic maintenance, mechanical maintenance, and machine operations.

The complete training package shall not be less than 8 days, of which 5 shall be for operator training and 3 shall be for mechanical and electrical maintenance training. Training shall be conducted within 5 workdays after installation of the machine and completion of all acceptance tests. A follow-up training class of not less than 2 days shall be conducted approximately 30 days following completion of the initial training. The two training classes shall not be conducted simultaneously. All training shall consist of an 8-hour workday, Monday through Thursday, excluding Government holidays, and shall be conducted at the installation site.

3.7.1 Operator training.

Operator training shall be provided for four operators for the Army Depot. The training shall familiarize the operators with the equipment and its characteristics and capabilities. The training shall include both a practical and hands-on familiarization with the equipment provided.

3.7.2 Mechanical maintenance training.

Four mechanical maintenance technicians for the Army Depot shall receive training in the mechanical functions of the equipment provided. At a minimum, the training shall include the following:

- 3.7.2.1 A review of mechanical diagrams and drawings.
- 3.7.2.2 Component location and function.
- 3.7.2.3 Troubleshooting procedures and techniques.
- 3.7.2.4 Repair procedures.
- 3.7.2.5 Assembly/disassembly procedures.
- 3.7.2.6 Adjustments (how, when, and where).
- 3.7.2.7 Preventive maintenance procedures.
- 3.7.2.8 Lubrication (points, type, and frequency).

3.7.3 Electrical and electronic maintenance training.

Two electrical technicians for the Army Depot shall receive training in the electrical and electronic functions of the equipment provided. At a minimum, the training shall include the following:

- 3.7.3.1 A review of the electrical and electronic systems, including wiring diagrams and drawings.
- 3.7.3.2 Troubleshooting procedures for the equipment and controls.
- 3.7.3.3 The use of diagnostics to locate the cause of malfunctions.
- 3.7.3.4 Electrical and electronic equipment servicing and care.
- 3.7.3.5 Procedures for adjustments (locating components, adjustments to be made, values to be measured, and equipment required to make adjustments).
- 3.7.3.6 Circuit board repair procedures where applicable (with schematics provided).

3.8 Characteristics of subordinate elements.

3.8.1 Dials.

Dial diameters shall be such that graduations may be read from the normal operating position. Dials shall be permanently and legibly engraved or etched on a nonglare background.

3.8.2 Digital readouts.

All digital readouts shall display data in illuminated figures clearly legible at a distance of 10 feet and give direct horizontal readings without requiring any calculation or interpolation. Each digit of the readout display shall be of the in-line type.

3.8.3 Gears.

The gears used in the machine and its components shall be machined in either the English or metric system. All gears shall meet the requirements of AGMA 360. The conversion factors and methods specified in ANSI Z210.1 shall be used for conversion of metric units (SI) to U.S. Customary System of Units (US) for comparison purposes.

3.9 Precedence.

In the event of conflict between the requirements of Section 3, functional requirements shall take precedence over physical requirements. If conflicting information exists, the contractor shall notify the contracting agency of each instance.

3.10 Qualification.

The contractor shall notify the contracting agency no later than 30 calendar days prior to validation of item performance. Final testing and acceptance shall be performed at the installation site. The contractor shall confirm the requirements of Section 4.3 during validation. In the event of failure of validation inspection, the contractor shall correct all observed deficiencies and retest.

4.0 QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection.

Unless otherwise specified in the contract or purchase order, the contractor is responsible for the performance of all inspection requirements (examinations and tests) as specified herein. Except as otherwise specified in the contract or purchase order, the contractor may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the government. The government reserves the right to perform any of the inspections set forth in this specification when they are deemed necessary to ensure that supplies and services conform to prescribed requirements.

4.1.1 Responsibility for compliance.

All items shall meet all requirements of Sections 3 and 5. The absence of any inspection requirements in the specification shall not relieve the contractor of the responsibility of ensuring that all products or supplies submitted to the government for acceptance comply with all requirements of the contract.

4.2 Quality conformance inspection.

Quality conformance inspections will consist of the examinations and test in Section 4.3. The quality conformance inspections will be applied to each item prior to acceptance of the system under the terms of the contract. Failure of any item to pass the examination or test shall be cause for rejection.

4.3 Methods of inspection.

4.3.1 Operational test.

The system provided shall be tested by the receiving activity after completion of installation, training, and demonstration of the system by the contractor. Satisfactory completion of all tests is inherent in this specification, and any cost associated in the correction of defects at the site shall be the responsibility of the contractor. The receiving activity's personnel can operate the ion vapor deposition system for a minimum of 8 hours without the need for correction of any defects. Proper operation and function of the ion vapor deposition system and its controls, motors, and other associated equipment will be verified during this trial period.

4.3.2 Examination.

The equipment and structure will be visually and physically examined for design, construction, material, components, electrical equipment, workmanship, form, fit, and function to determine compliance with the requirements of this specification.

4.3.3 Documentation.

The technical materials will be reviewed to ensure compliance with the requirements of paragraph 3.5 of this specification.

4.3.4 Reliability.

The contractor shall demonstrate that the reliability requirements of paragraph 3.3.14 have been satisfied.

4.3.5 Preacceptance

Preacceptance shall consist of full assembly and testing of the system prior to shipment to the Government site. Testing will be observed by an authorized Government representative.

4.3.6 Performance test.

The Tobyhanna Army Depot reserves the right to perform any or all of the performance tests to assure full compliance with this specification.

4.3.6.1 Coating appearance.

The ion-vapor-deposited aluminum coating shall be smooth, fine-grained, adherent, uniform in appearance, and free from pits, burning porosity, and other defects. The coating shall show no indication of contamination or improper operation of the equipment used to produce the deposit, such as excessively powdered coatings.

Any slight discoloration of the coating on test coupons is removed by glass-bead peening. All details of workmanship shall conform to the best practice for high-quality coatings. Type II parts processed in accordance with MIL-C-5541C requirements shall have a continuous, distinctly colored protective film ranging in color from yellow and iridescent bronze through olive drab and brown.

4.3.6.2 Adhesion.

The adhesion test will be performed on Type II test strips/parts processed in accordance with MIL-C-83488B.

4.3.6.3 Scraping test.

Adhesion will be determined by scraping the surface of the plated article to expose the basic metal and examining the surface at four diameters magnification for evidence of nonadhesion.

4.3.6.4 Corrosion resistance test.

A corrosion resistance test on a Type II coated steel part will be conducted in accordance with the procedures specified in ASTM Method B-117. This test will be conducted at an independent laboratory at the expense of Tobyhanna Army Depot. The parts shall show no evidence of corrosion of the basic metal when exposed for the following period of time:

Salt Spray Test

Class	Test Period (hours)
1	672
2	504
3	336

4.3.6.5 Vacuum level test.

The chamber/pumping system will be verified to be capable of pumping down to 8.5×10^{-6} Torr within 30 minutes with a dry, clean chamber.

4.3.6.6 Pressure levels.

Base pressure and time in minutes to reach base pressures with a clean, dry chamber will be established for the following system components:

- i. Roughing pump/blower.
- ii. Diffusion pump.
- iii. Holding pump.

5.0 PREPARATION FOR DELIVERY

5.1 General.

Preservation and packing shall be in accordance with ASTM-D3951-88, Standard Practice for Commercial Packaging.

5.2 Marking for shipment.

Marking shall be in accordance with Section 5 of MIL-STD-129J, Marking for Shipment and Storage. In addition, the following marking shall be on the equipment packaging:

"NOT FOR OUTSIDE STORAGE"

Contract number

5.3 Shipping, handling, and storage.

The contractor shall be responsible for all shipping, storage, and handling of the equipment and all materials. The Government shall not be responsible for furnishing any labor, equipment, or warehouse space for the loading, unloading, and storing of any materials. The contractor shall coordinate with the procurement department and the Contracting Officer the date and time at which the contractor may deliver his equipment to the building.

Appendix G

Draft Economic Analysis for Implementation of AIVD at TOAD

**ECONOMIC ANALYSIS
FOR HAZARDOUS WASTE MINIMIZATION TECHNOLOGY --
ALUMINUM ION VAPOR DEPOSITION
AT TOBYHANNA ARMY DEPOT**

Prepared by

**IT Corporation
Cincinnati, Ohio**

**Contract No. DACA31-91-D-0074
Task Order No. 6
IT Project No. 322244**

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Revised January, 1996

This economic evaluation was prepared by IT Corporation under contract to the U. S. Army Environmental Center (Contract No. DACA31-91-D-0074). The format and content of this document are based on examples provided to IT by Tobyhanna Army Depot, Corpus Christi Army Depot, and Anniston Army Depot. The document was prepared in accordance with the format specified by Tobyhanna Army Depot to facilitate its review by and usefulness to depot personnel. The basis of the economic evaluation are depot specific unit costs, rates, and factors that were supplied by depot personnel.

The views, opinions, and/or findings contained in this report should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other documentation.

The use of trade names in this report does not constitute an official endorsement or approval of the use of such commercial products. This report may not be cited for purposes of advertisement.

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I SUBMITTING ORGANIZATION

Tobyhanna Army Depot (TOAD)

II DATE OF SUBMISSION

(To be Determined)

III PROJECT TITLE

Aluminum Ion Vapor Deposition (AIVD), IP (To be Determined)

IV PROJECT FUNDING:

(To be Determined)

V OBJECTIVE OF ANALYSIS

The objective of this analysis is to evaluate the cost effectiveness of aluminum ion vapor deposition (AIVD) as an alternative process to cadmium electroplating for applying corrosion-resistant coatings to metal parts. AIVD does not generate waste or use hazardous materials, and reduces potential employee exposure to toxins. AIVD coatings provide equal or superior corrosion protection as compared to cadmium.

VI BACKGROUNDOperations

Depot maintenance, rebuilt, overhaul, and new fabrication activities include electroplating of metal parts. Electroplating is an electrochemical process during which dissolved metals are deposited on the surface of metal parts to provide corrosion resistance and other functional properties, or to replace surfaces that were either worn or machined away. Cadmium has several attributes as a surface coating and is commonly deposited over the surface of carbon steel to provide corrosion resistance. Cadmium electroplating has been used historically, and it is in current use at Tobyhanna Army Depot (TOAD).

Prior to plating, existing coatings (e.g., paints and electroplates) must be removed and the part cleaned. At TOAD, the Sandblast and Ultrasonics Shops remove paint, grease, and/or dust to prepare surfaces of parts for plating and painting. Parts commonly processed include electronic and mechanical repair items. Many of these items have been cadmium plated to prevent corrosion and to enhance paint adhesion. When stripped and cleaned, sandblast grit and cleaning effluents become contaminated with cadmium.

During plating, the metal part is placed in a bath of plating solution. An electric (DC) current is applied to the solution and the part: the part is negatively charged and the solution is positively charged. Dissolved cadmium in the bath migrates through the solution and deposits on the surface of the part. After plating, the parts are rinsed. Rinse waters from cadmium plating at TOAD are

treated in the on-site Industrial Wastewater Treatment Plant (IWTP). A cadmium-contaminated sulfide sludge, which is a RCRA hazardous waste (D006), is generated by the IWTP.

At the current workload about one drum of sandblast waste is generated each week. Over 20,000 pounds of sulfide sludge is generated each year by the IWTP. Approximately one 55-gallon drum of sludge is generated every month from parts washing operations.

These wastes are contaminated with cadmium and are RCRA hazardous wastes. Disposal of hazardous wastes is becoming increasingly more expensive and has implications of long term liabilities. In addition to the actual disposal and associated laboratory testing costs, considerable time is required for preparing waste for disposal, tracking the wastes, and processing the necessary paperwork. The State of Pennsylvania, the U. S. Environmental Protection Agency (USEPA), and the Army require the preparation of periodic reports on hazardous wastes generated. In an effort to eliminate the hazardous wastes generated by the Sandblast, Ultrasonic and Plating Shops at TOAD, a process change is being considered that would reduce the amount of cadmium entering these waste streams.

To accomplish this objective, AIVD can potentially be utilized in lieu of cadmium plating. This analysis investigates the use of the AIVD process as a substitute for cadmium plating.

Regulations

According to Public Law 101-189, effective November 29, 1989, the Secretary of Defense required each military department to establish a program to reduce the volume of solid and hazardous waste disposed of, and hazardous materials used by each depot maintenance installation. Target goals were assigned to measure the achievement of minimization and 1993 was established as the base year for purposes of measurement.

The USEPA published guidelines in the Federal Register on May 29, 1993, that define the elements of a hazardous waste minimization program. These guidelines emphasize source reduction as the preferred method of minimization followed by reuse, recycling, treatment, and disposal (listed in order of preference). The substitution of aluminum for cadmium electroplating is an example of source reduction.

Recently, the Occupational Safety and Health Administration (OSHA) lowered the permissible exposure levels for cadmium (Federal Register, January 20, 1993). These regulations affect the amount of cadmium to which employees can be exposed during the course of their work day. Eliminating or minimizing the use of cadmium plating will have an immediate beneficial effect on employee health by reducing or eliminating this potential to exposure.

Benefit

AIVD requires specialized equipment and a controlled environment. The process coats surfaces with aluminum, which provides corrosion protection and other functional properties. Implementation of AIVD would reduce or eliminate cadmium that contaminates a majority of the waste streams generated at TOAD.

Converting to an aluminum coating will enhance the depot's capability to meet present and future USEPA, OSHA, state, and local environmental laws. Utilization of this technology will reduce the potential for harm to human health or the environment by reducing the amount of toxic metal (i.e., cadmium) that is handled.

Due to the long life cycle of items repaired at TOAD, the total payback from this project will not be realized until the items repaired or fabricated using this process return for maintenance. The long-term savings, based on the 20 year economic life analysis shown in Format A-1, is estimated to be \$1,573,720 (Attachment 2).

Based on the analysis presented herein, acquisition of an AIVD system appears to be in the best interest of Tobyhanna Army Depot. It will have a long-term impact on the reduction of waste. In calendar year 1992 (CY92), nearly 65 percent of all hazardous waste generated at TOAD was contaminated with cadmium.¹ Most of these waste streams were contaminated through the blasting and cleaning of cadmium-plated surfaces of parts returned to the depot for maintenance. By replacing cadmium-plating with AIVD, the greatest source of cadmium contamination in depot wastes eventually will be eliminated. Although the payback will be long term, it is prudent to reduce cadmium usage wherever possible in light of the current tightening of regulations concerning cadmium. This economic analysis reflects the contributions made by the Pollution Prevention Team and the management philosophy at the installation. This investment is required to allow the depot to keep pace with changing environmental law, modernization, and technology. This equipment will complement other pollution prevention efforts planned by the installation.

A detailed cost analysis follows.

VII ASSUMPTIONS AND CONSTRAINTS

1. Funding for the equipment will be from obtained the installation Defense Business Operating Fund (DBOF). The criterion for funding by this program is that the equipment must generate enough savings in disposal and related costs to pay for itself over the course of its useful life or, with DA approval, that the project be beneficial to human health and the environment.
2. The equipment class for the AIVD equipment is 4940-, and a twenty year economic life will apply for all alternatives investigated in this analysis. The residual value is assumed negligible after 20 years of operation.
3. It is assumed that the plating shop workload requirements described in this analysis will remain constant or increase throughout the life of this project.
4. All cost savings will be discounted to FY95 dollars, using a 2.8 percent discount factor (AR 5-4).

5. Cost estimates for the proposed system are engineering estimates based on equipment manufacturer's data. Actual costs and savings may vary with the equipment actually purchased and changes in labor and utility rates.
6. This analysis assumes a 251 day work year.
7. It is assumed that electrical equipment is 80% efficient.²
8. The cost of hazardous waste disposal will increase yearly over the life of the project.
9. The cost of replacement chemicals will increase yearly over the life of the project.
10. Eighty percent of the workload that is cadmium plated can be converted to the AIVD process. This assumption is based on best judgement and not on a comprehensive survey of parts.
11. The costs for "cradle-to-grave" liability of disposed hazardous materials will increase yearly and be cumulative. (Environmental laws hold the generator responsible for the cleanup of any hazards associated with wastes generated.) The potential liability for the cradle-to-grave disposal risks is assumed to be \$10/kg.³
12. Based upon CY92 figures, at least 44 percent of the wastes generated by TOAD potentially could be eliminated by the use of AIVD.⁴
13. The policy of maintaining mobilization capacity per DODI 4515.15 and AR 750-2 will continue.
14. The DOD directive instructing all depots to decrease the amount of hazardous waste generated will remain in effect.
15. All operations will be consistent with applicable Federal, State, and local laws and regulations, and all depot safety requirements will be met.
16. Pollution prevention will continue to be a program of highest priority in the Department of Defense.

VIII ALTERNATIVES

Viable Alternatives

Alternative 1 - Status Quo. Continue to operate the cadmium plating process in the Plating Shop and maintain existing surface preparation processes in the Sandblast and Ultrasonic Shops. All these shops will continue to

generate cadmium contaminated waste streams requiring disposal as hazardous waste.

Alternative 2 -

Procure equipment to implement the AIVD process. The purchase and installation of AIVD equipment will significantly reduce the hazardous waste generated by the plating and the blasting and cleaning operations. Based upon CY92 figures on the generation of cadmium contaminated hazardous wastes, at least 44 percent of the wastes generated by Tobyhanna could potentially be eliminated by the use of AIVD.⁵ Therefore, this is a viable alternative and merits further consideration.

Non-Viable Alternatives

Alternative 3 -

Rent equipment on a short-term, as-required basis. This equipment is used on a recurring and regular basis. Therefore, this is not considered to be a viable alternative.

Alternative 4 -

Lease/lease-to-purchase equipment or lease with option-to-purchase equipment. This equipment would be required to be physically installed at the depot for an extended period of time and would require special modifications to the building. Therefore, leasing of AIVD equipment is not considered to be a viable alternative.

Alternative 5 -

Rebuild/Overhaul equipment. This equipment is an emerging technology and no equipment of this nature is owned by the government and available for rebuild/overhaul. Therefore, this is not considered to be a viable alternative. (However, the availability of equipment at facilities closed by the most recent BRAC list should be investigated.)

Alternative 6 -

Upgrade/Retrofit Equipment. This equipment is an emerging technology and no equipment of this nature is owned by the government and available for upgrade/retrofit. Therefore, this is not considered to be a viable alternative.

Alternative 7 -

Borrow Equipment. No other organization on the installation has this equipment. Therefore, this is not a viable alternative.

Alternative 8 -

Contract Equipment. No known organization provides this type of service. Therefore, this will remain a government function. This, then, is not a viable alternative.

Alternative 9 -

Consolidate Functions. The operations in the Plating, Sandblast, and Ultrasonic Shops are unique and specialized. Therefore, these cannot be consolidated with other operations. This is not a viable alternative.

IX COST ANALYSIS

Alternative One - Status Quo: Continue Cadmium Plating.

A. Current assets required: There is no equipment acquisition associated with this alternative. Therefore, only recurring costs will be associated with this alternative.

B. Recurring costs: Recurring costs associated with this alternative are as follows:

- (I) Costs of Waste Disposal
 - (a) process wastes
 - (b) sandblast grit removal
 - © sludge disposal from IWTP
 - (d) miscellaneous wastes

- (ii) Labor Costs for Waste Disposal

- (iii) Cost of Drums

- (iv) Cost of Cadmium Plating

- (a) plating labor
 - (b) purchase of rinse water
 - © rinse water treatment
 - (d) chemical consumption
 - (e) utilities

- (v) Potential Future Liability

- (I) Costs of Waste Disposal

For CY93, 104,663 lbs of cadmium-related wastes (EPA Waste Code D006) were generated and disposed of in 463 drums.⁶ The wastes were identified as follows:

Waste Type	No. of Drums	Weight (lbs)	Disposal Cost
Process Waste	244	28,336	\$25,087.73
Sandblast Grit Removal	58	34,818	\$12,186.30
IWTP Sludge Disposal	51	24,701	\$11,897.00
Miscellaneous Wastes	110	16,778	\$ 6,813.29
CY93 TOTALS	463	104,663	\$55,984.32

In addition, cadmium contaminated dust that is collected in a large baghouse is removed and disposed approximately once every five years.⁷ This baghouse currently holds

approximately 100,000 lbs of dust. Assuming a disposal cost of \$0.35/lb (the same as for other sandblast grit disposal) and apportioning the cost over five years, annual cost of disposal of this waste is \$7,000. Using the same density for this waste as for other sandblast grit (600 lbs/drum), the total number of drums of this waste generated per year is 165 drums.

The total D006 waste disposed annually is estimated to be:

No. of Drums = 628
Total Weight = 124,663 lbs
Total Annual Cost = \$62,984

(ii) Labor Costs for Waste Disposal

Labor costs for material handlers from 5K300 are as follows:

- (a) The average labor rate of \$18.82/hr is comprised of a basic labor rate of \$11.92/hr, a fringe benefit rate of \$3.56/hr, and a leave rate of \$3.34/hr.⁸
- (b) Based on CY92 data, it is assumed that 24 percent of the time expended by material handlers was cadmium related.⁹

$$2 \text{ people} \times 8 \text{ hours/day} \times 3 \text{ days/week} \times 52 \text{ weeks/year} \times \$18.82/\text{hr} \times 0.24 = \$11,274.$$

(iii) Cost of drums

Cost to purchase each drum is \$35.00.¹⁰ Therefore, total drum cost = \$35.00 x 628 = \$21,980.

(iv) Cost of Cadmium Plating

(a) Plating Labor

Four platers are required to perform cadmium plating.¹¹ All employees are on the day shift. The average labor cost for the Plating Shop is \$19.93/hr, and is comprised of a basic labor rate of \$13.03/hr, a fringe benefit rate of \$3.56/hr, and a leave rate of \$3.34/hr. Therefore the labor costs associated with cadmium plating are as follows:

$$\begin{aligned} \text{Total Labor Cost} &= (\$19.93/\text{hr}) \times (4 \text{ employees}) \times (2000 \text{ hrs/yr}) \\ &= \$159,440 \text{ per year} \end{aligned}$$

(b) Purchase of Rinse Water

The cadmium plating operation generates an average of 4,800 gallons of rinse water per day.¹²

$$\begin{aligned}\text{Rinse Water Flow Rate} &= (4,800 \text{ gal/day}) (251 \text{ day/yr}) \\ &= 1,200,000 \text{ gallons per year}\end{aligned}$$

Water costs \$0.00173 per gallon.¹³ The water purchase cost is as follows:

$$\begin{aligned}\text{Water Purchase Cost} &= (1,200,000 \text{ gal/yr}) \times (\$0.00173/\text{gal}) \\ &= \$2,076 \text{ per year}\end{aligned}$$

© Rinse Water Treatment

The IWTP treats the rinse waters for removal of cadmium. The cost to treat the rinse water in the IWTP is estimated at \$0.03 per gallon.¹⁴

$$\begin{aligned}\text{Water Treatment Cost} &= (1,200,000 \text{ gal/yr}) (\$0.03/\text{gal}) \\ &= \$36,000 \text{ per year}\end{aligned}$$

(d) Chemical Consumption

Plating operations deplete the chemicals in the tanks. Therefore, chemicals must be added periodically to replenish the ones removed during the plating operations. The estimated annual chemical consumption cost is \$20,000 per year.¹⁵

(e) Utility Costs

No utility cost is attributable solely to the above-mentioned aspects of the plating shop.¹⁶

(v) Potential Future Liability

A possibility exists that hazardous waste generated by the cleaning shops could become a potential liability at some time in the future. This liability could be as much as \$10.00 per kilogram of waste.¹⁷ To calculate this potential liability, we use the annual volume from the plating process of 124,663 pounds:

$$\begin{aligned}\text{Potential future liability} &= (124,663 \text{ lbs}) \times (0.454 \text{ kg/lb}) \times (\$10/\text{kg}) \\ &= \$565,970 \text{ potential liability}\end{aligned}$$

The cost of potential future liability is included for information only; it is not used in the economic analysis.

C. Total Recurring Costs Per Year - Alternative One

Costs of Waste Disposal	\$62,984
Labor Costs for Waste Disposal	\$11,274
Cost of Drums	\$21,980
Plating Labor Cost	\$159,440
Purchase of Rinse Water	\$2,076

Rinse Water Treatment	\$36,000
Chemical Consumption	\$20,000
TOTAL	\$313,754

Alternative Two - Procure Equipment to Perform the AIVD Process

This alternative requires a new investment in an AIVD system, including ancillary equipment, which will apply a uniform aluminum coating on steel parts. This coating is a direct replacement for cadmium plating and generates no hazardous waste. This process is applicable to 80% of the current cadmium plating workload. The process cannot be applied to all parts currently cadmium coated. Therefore, some parts will still require cadmium plating.

A. **New Investment:** The AIVD system will consist of a 6 foot by 10 foot vacuum chamber, vacuum pumping system, closed loop water cooling system, and control instruments. Additionally a standard rack and barrel accessory shall be provided. The costs of the AIVD system are as follows:¹⁸

AIVD Unit	\$490,000
Parts Racks (2)	\$45,350
Barrel Rack	\$40,783
Cryopump	\$35,949
Shipping and Installation	\$45,000
Miscellaneous Spare Parts	\$23,000
Blast Booths (2)	\$20,000
Construction of Facilities	\$50,000
 Total Installed Cost	 \$750,082

B. **Recurring costs:** The recurring costs associated with this alternative are:

- (I) cost of waste disposal associated with cadmium plating
- (ii) cost of residual cadmium plating
- (iii) labor costs for operation and preventive maintenance
- (iv) utility costs
- (v) material costs
- (vi) maintenance and repair costs.

(I) Cost of Waste Disposal Associated with Cadmium Plating

If it is assumed that 44 percent of the wastes generated at Tobyhanna would be eliminated by the use of AIVD, then 56 percent of the wastes generated would remain.¹⁹ The cost of waste disposal associated with cadmium plating determined for Alternative 1 included the cost of waste disposal, labor costs for waste disposal, and the cost of drums, or

$$\begin{aligned}\text{Cost of cadmium plating waste disposal} &= \$62,984 + \$11,274 + \$21,980 \\ &= \$96,238 \text{ per year}\end{aligned}$$

$$\begin{aligned}\text{If 56 percent of that total remains, then the cost of waste disposal associated with cadmium plating following implementation of AIVD} &= \$96,238 \times 0.56 \\ &= \$53,893 \text{ per year}\end{aligned}$$

(ii) Cost of Residual Cadmium Plating

Twenty percent of the cadmium workload cannot be processed in the AIVD system. Therefore, 20 percent of the operating costs (plating labor cost, purchase of rinse water, rinse water treatment, and chemical consumption) will remain after the purchase of the new equipment. The total plating cost is

$$\begin{aligned}\text{Plating cost} &= \$159,440 + \$2,076 + \$36,000 + \$20,000 \\ &= \$217,516\end{aligned}$$

20 percent of this total is

$$\begin{aligned}\text{Cost of Residual Cadmium Plating} &= \$217,516 \times 0.20 \\ &= \$43,503\end{aligned}$$

(iii) Labor Costs for Operation and Preventive Maintenance

Four personnel are required to operate the AIVD system - two personnel to prepare and finish parts and two personnel to operate the equipment.²⁰

The majority of parts coated at Tobyhanna are small parts typically coated in a barrel coater. Therefore, it would not be possible to estimate the operation of the AIVD system on the basis of parts processed. Instead, it is assumed that the AIVD system would be operated three cycles a week to process all required parts.

$$\begin{aligned}\text{Number of Cycles} &= (3 \text{ cycles/week}) \times (50 \text{ weeks/year}) \\ &= 150 \text{ cycles per year}\end{aligned}$$

Personnel from the existing plating operations will operate the equipment. The hourly rate for this Work Center is \$19.93 per hour. The labor cost for the operation of the AIVD system is as follows:

$$\begin{aligned}\text{Labor Cost} &= (4 \text{ employees}) \times (150 \text{ days}) \times (8 \text{ hrs/day}) \times (\$19.93/\text{hr}) \\ &= \$95,664 \text{ per year}\end{aligned}$$

(iv) Utility Costs

Utility Costs include utilities and argon gas costs. Electricity costs \$0.05 per kWh.²¹ The equipment requires 480 Volts at 200 Amperes for one hour during each cycle and the AIVD system is 80% efficient on power usage.²² Therefore, the utility cost is calculated as follows:

$$\begin{aligned}\text{Utility Cost} &= (480 \text{ Volts}) \times (200 \text{ Amperes}) \times (1 \text{ Watt/Volt-Ampere}) \times (1/0.80) \times \\ &\quad (1\text{kW}/1000\text{W}) \times \sqrt{3} \times (\$0.05/\text{kWh}) \times (150 \text{ cycles/yr}) \times (1\text{hr/cycle}) \\ &= \$1,558 \text{ per year}\end{aligned}$$

Argon gas is used to purge the vacuum chamber of impurities and also acts as an electron transfer media during discharge cleaning and aluminum coating. One and a half cubic feet of argon gas is required for each cycle.²³ Argon costs \$1.65 per gallon (liquid).²⁴ The equivalent volume in standard cubic feet (SCF) is 112.4 SCF per gallon. The argon gas cost is calculated as follows:

$$\begin{aligned}\text{Argon Cost} &= (1.5 \text{ SCF/cycle}) \times (150 \text{ cycles/yr}) \times (\$1.65/\text{gal}) \times (1 \text{ gal}/112.4 \text{ cubic ft}) \\ &= \$4 \text{ per year}\end{aligned}$$

(v) Material Costs

The crucibles required to vaporize the aluminum wire are expendable and require replacement once every 80 cycles or approximately once every 6 months based on 150 cycles/year.²⁵ The AIVD system has 7 crucibles, the replacement cost is \$25.00 each.²⁶

$$\begin{aligned}\text{Crucible Cost} &= (12 \text{ months/yr}) \times (7 \text{ crucibles}/6 \text{ months}) \times (\$25.00 \text{ each}) \\ &= \$350 \text{ per year}\end{aligned}$$

The AIVD system consumes aluminum wire at a rate of 1.2 pounds per cycle, and the wire costs \$6.00 per pound.²⁷ The wire cost is calculated as follows:

$$\begin{aligned}\text{Wire Cost} &= (1.2 \text{ lbs/cycle}) (150 \text{ cycles/yr}) (\$6.00/\text{lb}) \\ &= \$1,080 \text{ per year}\end{aligned}$$

(vi) Maintenance and Repair Costs

Preventive maintenance and operator maintenance must be performed monthly and can be performed at the same time. These costs are calculated as follows:

$$\begin{aligned}\text{Operator Maintenance Cost} &= (4 \text{ employees}) \times (12 \text{ days/yr}) \times (8 \text{ hrs/day}) \times (\$19.93/\text{hr}) \\ &= \$7,653 \text{ per year}\end{aligned}$$

Preventive maintenance is estimated to require 240 manhours per year.²⁸ Therefore, the maintenance and repair cost is calculated as follows:

$$\begin{aligned} \text{Maintenance Labor} &= (240 \text{ hrs/yr}) (\$19.93/\text{hr}) \\ &= \$4,783 \text{ per year} \end{aligned}$$

C. Total Recurring Costs Per Year - Alternative Two

Cost of Waste Disposal Associated with Cadmium Plating	\$53,893
Cost of Residual Cadmium Plating	\$43,503
Labor Costs for Operation and Preventive Maintenance	\$95,664
Utility Costs	\$1,558
Argon Cost	\$4
Material Costs	\$1,430
Maintenance and Repair Costs	\$12,436
 TOTAL	 \$208,488

D. Terminal Value

The terminal value of the AIVD system is assumed to be negligible since it is likely that any salvage value remaining after 20 years operation would likely be completely offset by removal, dismantling, or disposal costs.²⁹

Using straight line depreciation,

$$\$750,082/20 = \$37,504 \text{ depreciation/yr}$$

X BENEFITS ANALYSIS

The benefits analysis consists of evaluating Alternatives 1 and 2 in the following categories:

- reduction of liability,
- corrosion protection,
- conservation of water, and
- employee safety.

1. Reduction of Liability - The degree to which each alternative is able to decrease liability of chemical disposal in permitted landfills.

a. Alternative 1 - The current process generates 124,663 pounds of cadmium sludge each year which is disposed of in a landfill. The Environmental Protection Agency's policy on land disposal is that the waste generator is responsible for the material from "Cradle to Grave." This means that even though the Depot has paid for the disposal of the waste, if a problem in the landfill results in contamination of the environment, the Depot may be liable for the cleanup.

b. Alternative 2. This process generates no waste for disposal in a landfill. Initially, existing cadmium coated parts returning for maintenance would continue to generate

wastes. However, in the long run, as cadmium coated parts are replaced by AIVD coated parts, this waste would be gradually reduced and eventually eliminated. Therefore, long term liabilities would be reduced.

2. Corrosion Protection - The degree to which each alternative is able to provide corrosion protection for the part.
 - a. Alternative 1. Cadmium plating is the specified coating for protection of steels in corrosive atmospheres. Cadmium meets the American Society of Testing Materials (ASTM) Standard B117, salt spray test for corrosion.
 - b. Alternative 2. Ion vapor deposition of aluminum provides a coating superior to cadmium when tested under the same conditions. Aluminum develops a protective oxide film on its surface which effectively retards corrosion, making it superior to cadmium.
3. Conservation of Water - The degree to which each alternative is able to conserve water.
 - a. Alternative 1. This alternative consumes water at a rate of six gallons per minute or 1,200,000 gallons per year. This water must be treated at the IWTP and replaced.
 - b. Alternative 2. AIVD uses water to cool the coating chamber. This water is contained in a closed loop chilling system. Therefore, there is no water consumed with this process.
4. Employee Safety - The degree which each alternative provides a safe working environment for the employee.
 - a. Alternative 1. Cadmium plating is performed in a large open-top tank containing cadmium and sulfuric acid. Cadmium is regulated by the EPA and OSHA as a potential carcinogen.
 - b. Alternative 2. Ion vapor deposition of aluminum is performed inside a vacuum chamber. Aluminum metal is vaporized and ionized to have a positive charge. Argon gas is used to transfer the aluminum ions to the part. Employees are not exposed to solutions or gases during normal operations.

Employing Alternative 2 allows the installation to significantly reduce hazardous waste from the cleaning and plating operations as well as reducing potential employee exposure to cadmium. This demonstrates concern for the environment and employee health and safety. Utilizing this equipment will continue to establish Tobyhanna Army Depot as a state-of-the-art maintenance facility.

XI COST SUMMARY

The total (discounted) project cost and uniform annual cost of the two viable alternatives are shown below. A detailed cost analysis of Alternatives 1 and 2 is provided in the cost analysis section and is shown in the attachments.

Alternative	Total Project Cost	Uniform Annual Cost
1 (Status Quo)	\$5,000,082	\$295,228
2 (AIVD Process)	\$4,166,229	\$245,994

XII BENEFIT SUMMARY

The following table presents a summary ranking of the alternatives related to various benefits and outputs of each. More complete discussion can be found in the benefits analysis section.

Benefits	Alternatives	
	1 (Status Quo)	2 (AIVD Process)
Reduction of Liability	Poor	Excellent
Corrosion Protection	Good	Excellent
Conservation of Water	Poor	Excellent
Employee Safety	Significant potential for exposures to toxic compounds	Very low potential for exposures

XIII SENSITIVITY ANALYSIS SUMMARY

A sensitivity analysis was performed to evaluate the effect of changes in the assumed constraints. There are two constraints in the Economic Analysis that were addressed:

1. Assumption 10 - 80% of the cadmium plating workload can be converted to the AIVD Process. This assumption was made after research into the quantity, size and configuration of the parts was performed. It is an engineering estimate. Therefore, a sensitivity analysis was performed to evaluate the effect of the Economic Analysis if only 50% of the parts can be switched to the new process.
2. Assumption 3 - The plating shop workload requirements will remain constant or increase throughout the life of this project. A sensitivity analysis was performed to evaluate the effect of the Economic Analysis if the workload decreased by 20%.
3. The worst case would be the summation of the above analyses. Therefore, a sensitivity analysis was performed with only 50% of the parts being switched to the AIVD process and the workload decreasing by 20%.

A decrease in workload will have a negligible effect on electricity, equipment, construction, or building maintenance for either alternative, since square footage of buildings will not be affected.

Sensitivity Variable	Total Project Cost	
	Alternative 1	Alternative 2
1. 50% Converted to AIVD	\$5,000,082	\$4,518,988
2. 20% Workload Reduction	\$4,000,063	\$3,480,951
3. (1 and 2) Combined	\$4,000,063	\$3,762,847

The summary data for this sensitivity analysis are included in the attachments. The sensitivity analysis shows that based upon all stated assumptions, Alternative 2, implementation of the AIVD process, is the best alternative under all conditions.

XIV POST INVESTMENT ANALYSIS

The savings generated by the AIVD process may be documented by monitoring the number of parts processed through the AIVD system and the number of hours of operation. The amount of chemicals used can be obtained directly from chemists' records. A log book should be set up to record the number of parts reclaimed by the AIVD system.

Maintenance and repair costs are available from the Depot Equipment Division, Property Book Office and are documented by the equipment's bar code number. Utility costs are also calculated from the number of hours of operation.

XV RECOMMENDATION

Implementation of Alternative Two is recommended.

XVI REFERENCES

1. Estimate provided by Mike Parrent, TOAD, Chief, Hazardous Waste Branch.
2. Ibid.
3. Estimate provided by Ronald Stevenson, General Engineer, Sacramento Army Depot (SAAD), in The Economic Analysis for HAZMIN CTX Task Force, Electrowinning Equipment, August, 1991. Estimate assumed to remain accurate for 1993 dollars.
4. Estimate provided by Mike Parrent, TOAD, Chief, Hazardous Waste Branch.
5. Ibid.
6. Ibid.
7. Ibid.

8. Economic Analysis, Hazmin Reduction in Plating Operations, TOAD, May, 1992.
9. Estimate provided by Mike Parrent, TOAD, Chief, Hazardous Waste Branch.
10. Ibid.
11. Jim Holiday, SDSCC-EN, CCAD, 1993.
12. Ibid.
13. DF, SDSCC-EFF (200-1a), dated 21 October 1988, Subject: Economic Analysis of Hazardous Waste Minimization Initiatives.
14. Jim Holiday, SDSCC-EN, CCAD, 1993.
15. Ibid.
16. Economic Analysis -- Hazmin Reduction in Plating Operations, TOAD, May 1, 1992.
17. Estimate provided by Ronald Stevenson, General Engineer, SAAD, in The Economic Analysis for the HAZMIN CTX Task Force, Electrowinning Equipment, August, 1991. Estimate assumed to remain accurate for 1993 dollars.
18. Estimates based on budgetary quotes obtained from Abar Ipsen, Inc., and IVI Corp.
19. Estimate provided by Mike Parrent, TOAD, Chief, Hazardous Waste Branch.
20. Jim Holiday, SDSCC-EN, CCAD, 1993.
21. DF, SDSCC-EFF (200-1a), dated 21 October 1988, Subject: Economic Analysis of Hazardous Waste Minimization Initiatives.
22. Data was obtained from Abar Ipsen Industries literature and sales representative, Graham T. Legge, Bensalem, PA 19047.
23. Ibid.
24. Cameron Webb, CCAD, Director for Maintenance, Production Control Division, Metal Spray Shop Production Controller, AV (DSN) 861-2294.
25. Data was obtained from Abar Ipsen Industries literature and sales representative, Graham T. Legge, Bensalem, PA 19047.
26. Ibid.
27. Ibid.

28. Jim Folk, CCAD, Director of Engineering & Logistics, Depot Equipment Division, Installation Equipment Management Branch, Preventive Maintenance Section 1 Supervisor, AV (DSN) 861-2038.
29. Army Regulation (AR) 11-18, The Cost & Economic Analysis Program, May 7, 1990.

ATTACHMENT 1

FORMAT A FOR ALTERNATIVES 1 AND 2

**SUMMARY OF COSTS FOR ECONOMIC ANALYSIS/
PROGRAM EVALUATION STUDIES
FORMAT A**

1. Submitting DoD Component: Tobyhanna Army Depot
2. Date of Submission: _____
3. Project Title: Aluminum Ion Vapor Deposition (AIVD)
4. Description of Project Objective: Determine least costly process for coating steel parts.
5. Alternative: Status Quo (present)
6. Economic Life: 20 years

8. Program / Project Costs						
7. Project Year	a. Non-Recurring		b. Recurring	c. Annual Cost	d. Discount Factor	e. Discounted Annual Cost
	R & D	Investment	Operations			
0			\$0	\$0	1.000	\$0
1			\$313,754	\$313,754	0.986	\$309,481
2			\$313,754	\$313,754	0.960	\$301,052
3			\$313,754	\$313,754	0.933	\$292,852
4			\$313,754	\$313,754	0.908	\$284,875
5			\$313,754	\$313,754	0.883	\$277,116
6			\$313,754	\$313,754	0.859	\$269,568
7			\$313,754	\$313,754	0.836	\$262,226
8			\$313,754	\$313,754	0.813	\$255,083
9			\$313,754	\$313,754	0.791	\$248,136
10			\$313,754	\$313,754	0.769	\$241,377
11			\$313,754	\$313,754	0.748	\$234,803
12			\$313,754	\$313,754	0.728	\$228,407
13			\$313,754	\$313,754	0.708	\$222,186
14			\$313,754	\$313,754	0.689	\$216,134
15			\$313,754	\$313,754	0.670	\$210,247
16			\$313,754	\$313,754	0.652	\$204,521
17			\$313,754	\$313,754	0.634	\$198,950
18			\$313,754	\$313,754	0.617	\$193,531
19			\$313,754	\$313,754	0.600	\$188,260
20			\$313,754	\$313,754	0.584	\$183,132
21			\$313,754	\$313,754	0.568	\$178,144
9.	Totals	\$0	\$0	\$6,588,834	\$6,588,834	16.936
						\$5,000,082

- 10a. Total Project Cost (discounted) \$5,000,082
- 10b. Uniform Annual Cost (without terminal value) (9e. / 9d.) \$295,228
11. Less Terminal Value (discounted) \$0
- 12a. Net Total Project Cost (discounted) (10a. - 11.) \$5,000,082
- 12b. Uniform Annual Cost (with terminal value) (12a. / 9d.) \$295,228

**SUMMARY OF COSTS FOR ECONOMIC ANALYSIS/
PROGRAM EVALUATION STUDIES
FORMAT A**

1. Submitting DoD Component: Tobyhanna Army Depot
2. Date of Submission: _____
3. Project Title: Aluminum Ion Vapor Deposition (AIVD)
4. Description of Project Objective: Determine least costly process for coating steel parts.
5. Alternative: AIVD
6. Economic Life: 20 years

8. Program / Project Costs						
7. Project Year	a. Non-Recurring		b. Recurring	c. Annual Cost	d. Discount Factor	e. Discounted Annual Cost
	R & D	Investment	Operations			
0			\$0	\$0	1.000	\$0
1	\$0	\$750,082	\$313,754	\$1,063,836	0.986	\$1,049,348
2			\$208,488	\$208,488	0.960	\$200,047
3			\$208,488	\$208,488	0.933	\$194,599
4			\$208,488	\$208,488	0.908	\$189,298
5			\$208,488	\$208,488	0.883	\$184,142
6			\$208,488	\$208,488	0.859	\$179,127
7			\$208,488	\$208,488	0.836	\$174,248
8			\$208,488	\$208,488	0.813	\$169,502
9			\$208,488	\$208,488	0.791	\$164,885
10			\$208,488	\$208,488	0.769	\$160,394
11			\$208,488	\$208,488	0.748	\$156,025
12			\$208,488	\$208,488	0.728	\$151,775
13			\$208,488	\$208,488	0.708	\$147,642
14			\$208,488	\$208,488	0.689	\$143,620
15			\$208,488	\$208,488	0.670	\$139,708
16			\$208,488	\$208,488	0.652	\$135,903
17			\$208,488	\$208,488	0.634	\$132,201
18			\$208,488	\$208,488	0.617	\$128,601
19			\$208,488	\$208,488	0.600	\$125,098
20			\$208,488	\$208,488	0.584	\$121,691
21			\$208,488	\$208,488	0.568	\$118,376
9.	Totals	\$0	\$750,082	\$4,483,514	\$5,233,596	16.936
						\$4,166,229

10a. Total Project Cost (discounted)	<u>\$4,166,229</u>
10b. Uniform Annual Cost (without terminal value) (9e. / 9d.)	<u>\$245,994</u>
11. Less Terminal Value (discounted)	<u>\$0</u>
12a. Net Total Project Cost (discounted) (10a. - 11.)	<u>\$4,166,229</u>
12b. Uniform Annual Cost (with terminal value) (12a. / 9d.)	<u>\$245,994</u>

ATTACHMENT 2

FORMAT A-1

**ECONOMIC ANALYSIS/PROGRAM EVALUATION
SUMMARY OF COSTS FOR
FORMAT A-1**

1.	Submitting DoD Component: <u>Tobyhanna Army Depot</u>				
2.	Date of Submission: _____				
3.	Project Title: <u>Aluminum Ion Vapor Deposition (AIVD)</u>				
4.	Description of Project Objective: <u>Determine least costly process for coating steel parts.</u>				
5a.	Present Alternative: <u>Status Quo</u>		6a. Economic Life: <u>20 years</u>		
5b.	Proposed Alternative: <u>AIVD</u>		6b. Economic Life: <u>20 years</u>		
7. Project Year	8. Recurring (Operating) Costs		9. Differential Cost	10. Discount Factor	11. Discounted Differential Cost
	a. Present Alternative	b. Proposed Alternative			
0	\$0	\$0	\$0	1.000	\$0
1	\$313,754	\$313,754	\$0	0.986	\$0
2	\$313,754	\$208,488	\$105,266	0.960	\$101,004
3	\$313,754	\$208,488	\$105,266	0.933	\$98,253
4	\$313,754	\$208,488	\$105,266	0.908	\$95,577
5	\$313,754	\$208,488	\$105,266	0.883	\$92,974
6	\$313,754	\$208,488	\$105,266	0.859	\$90,441
7	\$313,754	\$208,488	\$105,266	0.836	\$87,978
8	\$313,754	\$208,488	\$105,266	0.813	\$85,582
9	\$313,754	\$208,488	\$105,266	0.791	\$83,251
10	\$313,754	\$208,488	\$105,266	0.769	\$80,983
11	\$313,754	\$208,488	\$105,266	0.748	\$78,777
12	\$313,754	\$208,488	\$105,266	0.728	\$76,632
13	\$313,754	\$208,488	\$105,266	0.708	\$74,544
14	\$313,754	\$208,488	\$105,266	0.689	\$72,514
15	\$313,754	\$208,488	\$105,266	0.670	\$70,539
16	\$313,754	\$208,488	\$105,266	0.652	\$68,618
17	\$313,754	\$208,488	\$105,266	0.634	\$66,749
18	\$313,754	\$208,488	\$105,266	0.617	\$64,931
19	\$313,754	\$208,488	\$105,266	0.600	\$63,162
20	\$313,754	\$208,488	\$105,266	0.584	\$61,442
21	\$313,754	\$208,488	\$105,266	0.568	\$59,768
9.	Totals	\$6,588,834	\$4,483,514	\$2,105,320	16.936
					\$1,573,720

**ECONOMIC ANALYSIS/PROGRAM EVALUATION
SUMMARY OF COSTS FOR
FORMAT A-1**

13a. Present Value of New Investment:

a. Land and Buildings	\$0
b. Equipment	<u>\$750,082</u>
c. Other (identify nature)	

Facility Modification	\$0
Process Development	\$0
Installation/Training/PM	<u>\$0</u>

Total Other	\$0
-------------	-----

d. Working Capital (Change—plus or minus)	\$0
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**14. Total Present Value of New Investment (i.e.,
Funding Requirements.)** **\$750,082**

**15. Plus: Value of existing assets to be
employed on the project.** \$0

16. Less: Value of existing assets replaced. \$0

17. Less: Terminal Value of new investment. \$0

18. Total New Present Value of Investment. **\$750,082**

**19. Present Value of Cost Savings from Operations
(Col. 11)** \$1,573,720

**20. Plus: Present Value of the Cost of Refurbishment
or Modifications Eliminated.** \$0

21. Total Present Value of Savings. **\$1,573,720**

**22. Savings/Investment Ratio.
(Line 21 divided by Line 18).** **2.098**

23. Rate of Return on Investment. **12.8%**

ATTACHMENT 3

RETURN ON INVESTMENT CALCULATION

**ECONOMIC ANALYSIS/PROGRAM EVALUATION
SUMMARY OF COSTS FOR
RETURN ON INVESTMENT**

1. Submitting DoD Component:	<u>Tobyhanna Army Depot</u>				
2. Date of Submission:					
3. Project Title:	<u>Aluminum Ion Vapor Deposition (AIVD)</u>				
4. Description of Project Objective:	<u>Determine least costly process for coating steel parts.</u>				
5a. Present Alternative:	<u>Status Quo</u>		6a. Economic Life: <u>20 years</u>		
5b. Proposed Alternative:	<u>AIVD</u>		6b. Economic Life: <u>20 years</u>		
7. Project Year	8. Net Investment	9. Operational Savings	10. Discount Factor at 12.8%	P.V. Investment	11. Discounted Differential Cost
0	\$0	\$0	1.000	\$0	\$0
1	\$750,082	\$0	0.943	\$707,672	\$0
2	\$0	\$105,266	0.837	\$0	\$88,084
3	\$0	\$105,266	0.742	\$0	\$78,123
4	\$0	\$105,266	0.658	\$0	\$69,289
5	\$0	\$105,266	0.584	\$0	\$61,453
6	\$0	\$105,266	0.518	\$0	\$54,504
7	\$0	\$105,266	0.459	\$0	\$48,341
8	\$0	\$105,266	0.407	\$0	\$42,874
9	\$0	\$105,266	0.361	\$0	\$38,026
10	\$0	\$105,266	0.320	\$0	\$33,726
11	\$0	\$105,266	0.284	\$0	\$29,912
12	\$0	\$105,266	0.252	\$0	\$26,530
13	\$0	\$105,266	0.224	\$0	\$23,529
14	\$0	\$105,266	0.198	\$0	\$20,869
15	\$0	\$105,266	0.176	\$0	\$18,509
16	\$0	\$105,266	0.156	\$0	\$16,416
17	\$0	\$105,266	0.138	\$0	\$14,559
18	\$0	\$105,266	0.123	\$0	\$12,913
19	\$0	\$105,266	0.109	\$0	\$11,453
20	\$0	\$105,266	0.096	\$0	\$10,158
21	\$0	\$105,266	0.086	\$0	\$9,009
9.	Totals	\$750,082	\$2,105,320	8.672	\$707,672
					\$708,275

ATTACHMENT 4

**SENSITIVITY ANALYSIS FOR SENSITIVITY VARIABLES 1, 2, AND 3
FOR ALTERNATIVES 1 AND 2**

**SUMMARY OF COSTS FOR ECONOMIC ANALYSIS/
PROGRAM EVALUATION STUDIES
FORMAT A
SENSITIVITY ANALYSIS I**

1. Submitting DoD Component: Tobyhanna Army Depot
2. Date of Submission: _____
3. Project Title: Aluminum Ion Vapor Deposition (AIVD)
4. Description of Project Objective: Determine least costly process for coating steel parts.
5. Alternative: Status Quo (present)
6. Economic Life: 20 years

8. Program / Project Costs

7. Project Year	a. Non-Recurring		b. Recurring	c. Annual Cost	d. Discount Factor	e. Discounted Annual Cost	
	R & D	Investment	Operations				
0			\$0	\$0	1.000	\$0	
1			\$313,754	\$313,754	0.986	\$309,481	
2			\$313,754	\$313,754	0.960	\$301,052	
3			\$313,754	\$313,754	0.933	\$292,852	
4			\$313,754	\$313,754	0.908	\$284,875	
5			\$313,754	\$313,754	0.883	\$277,116	
6			\$313,754	\$313,754	0.859	\$269,568	
7			\$313,754	\$313,754	0.836	\$262,226	
8			\$313,754	\$313,754	0.813	\$255,083	
9			\$313,754	\$313,754	0.791	\$248,136	
10			\$313,754	\$313,754	0.769	\$241,377	
11			\$313,754	\$313,754	0.748	\$234,803	
12			\$313,754	\$313,754	0.728	\$228,407	
13			\$313,754	\$313,754	0.708	\$222,186	
14			\$313,754	\$313,754	0.689	\$216,134	
15			\$313,754	\$313,754	0.670	\$210,247	
16			\$313,754	\$313,754	0.652	\$204,521	
17			\$313,754	\$313,754	0.634	\$198,950	
18			\$313,754	\$313,754	0.617	\$193,531	
19			\$313,754	\$313,754	0.600	\$188,260	
20			\$313,754	\$313,754	0.584	\$183,132	
21			\$313,754	\$313,754	0.568	\$178,144	
9.	Totals	\$0	\$0	\$6,588,834	\$6,588,834	16.936	\$5,000,082

- 10a. Total Project Cost (discounted) \$5,000,082
- 10b. Uniform Annual Cost (without terminal value) (9e. / 9d.) \$295,228
11. Less Terminal Value (discounted) \$0
- 12a. Net Total Project Cost (discounted) (10a. – 11.) \$5,000,082
- 12b. Uniform Annual Cost (with terminal value) (12a. / 9d.) \$295,228

**SUMMARY OF COSTS FOR ECONOMIC ANALYSIS/
PROGRAM EVALUATION STUDIES
FORMAT A
SENSITIVITY ANALYSIS I**

1. Submitting DoD Component: Tobyhanna Army Depot

2. Date of Submission: _____

3. Project Title: Aluminum Ion Vapor Deposition (AIVD)

4. Description of Project Objective: Determine least costly process for coating steel parts.

5. Alternative: AIVD

6. Economic Life: 20 years

8. Program / Project Costs						
7. Project Year	a. Non-Recurring		b. Recurring	c. Annual Cost	d. Discount Factor	e. Discounted Annual Cost
	R & D	Investment	Operations			
0			\$0	\$0	1.000	\$0
1	\$0	\$750,082	\$313,754	\$1,063,836	0.986	\$1,049,348
2			\$232,084	\$232,084	0.960	\$222,688
3			\$232,084	\$232,084	0.933	\$216,623
4			\$232,084	\$232,084	0.908	\$210,722
5			\$232,084	\$232,084	0.883	\$204,983
6			\$232,084	\$232,084	0.859	\$199,400
7			\$232,084	\$232,084	0.836	\$193,969
8			\$232,084	\$232,084	0.813	\$188,685
9			\$232,084	\$232,084	0.791	\$183,546
10			\$232,084	\$232,084	0.769	\$178,547
11			\$232,084	\$232,084	0.748	\$173,684
12			\$232,084	\$232,084	0.728	\$168,953
13			\$232,084	\$232,084	0.708	\$164,351
14			\$232,084	\$232,084	0.689	\$159,875
15			\$232,084	\$232,084	0.670	\$155,520
16			\$232,084	\$232,084	0.652	\$151,284
17			\$232,084	\$232,084	0.634	\$147,164
18			\$232,084	\$232,084	0.617	\$143,155
19			\$232,084	\$232,084	0.600	\$139,256
20			\$232,084	\$232,084	0.584	\$135,463
21			\$232,084	\$232,084	0.568	\$131,773
9.	Totals	\$0	\$750,082	\$4,955,434	\$5,705,516	16.936
						\$4,518,988

10a. Total Project Cost (discounted)	<u>\$4,518,988</u>
10b. Uniform Annual Cost (without terminal value) (9e. / 9d.)	<u>\$266,822</u>
11. Less Terminal Value (discounted)	<u>\$0</u>
12a. Net Total Project Cost (discounted) (10a. - 11.)	<u>\$4,518,988</u>
12b. Uniform Annual Cost (with terminal value) (12a. / 9d.)	<u>\$266,822</u>

**SUMMARY OF COSTS FOR ECONOMIC ANALYSIS/
PROGRAM EVALUATION STUDIES
FORMAT A
SENSITIVITY ANALYSIS II**

1. Submitting DoD Component: Tobyhanna Army Depot
2. Date of Submission: _____
3. Project Title: Aluminum Ion Vapor Deposition (AIVD)
4. Description of Project Objective: Determine least costly process for coating steel parts.
5. Alternative: Status Quo (present)
6. Economic Life: 20 years

8. Program / Project Costs						
7. Project Year	a. Non-Recurring		b. Recurring	c. Annual Cost	d. Discount Factor	e. Discounted Annual Cost
	R & D	Investment	Operations			
0			\$0	\$0	1.000	\$0
1			\$251,003	\$251,003	0.986	\$247,585
2			\$251,003	\$251,003	0.960	\$240,841
3			\$251,003	\$251,003	0.933	\$234,281
4			\$251,003	\$251,003	0.908	\$227,900
5			\$251,003	\$251,003	0.883	\$221,693
6			\$251,003	\$251,003	0.859	\$215,654
7			\$251,003	\$251,003	0.836	\$209,780
8			\$251,003	\$251,003	0.813	\$204,067
9			\$251,003	\$251,003	0.791	\$198,508
10			\$251,003	\$251,003	0.769	\$193,102
11			\$251,003	\$251,003	0.748	\$187,842
12			\$251,003	\$251,003	0.728	\$182,726
13			\$251,003	\$251,003	0.708	\$177,749
14			\$251,003	\$251,003	0.689	\$172,907
15			\$251,003	\$251,003	0.670	\$168,198
16			\$251,003	\$251,003	0.652	\$163,616
17			\$251,003	\$251,003	0.634	\$159,160
18			\$251,003	\$251,003	0.617	\$154,825
19			\$251,003	\$251,003	0.600	\$150,608
20			\$251,003	\$251,003	0.584	\$146,506
21			\$251,003	\$251,003	0.568	\$142,515
9.	Totals	\$0	\$0	\$5,271,063	16.936	\$4,000,063

- 10a. Total Project Cost (discounted) \$4,000,063
- 10b. Uniform Annual Cost (without terminal value) (9e. / 9d.) \$236,183
11. Less Terminal Value (discounted) \$0
- 12a. Net Total Project Cost (discounted) (10a. – 11.) \$4,000,063
- 12b. Uniform Annual Cost (with terminal value) (12a. / 9d.) \$236,183

**SUMMARY OF COSTS FOR ECONOMIC ANALYSIS/
PROGRAM EVALUATION STUDIES
FORMAT A
SENSITIVITY ANALYSIS II**

1. Submitting DoD Component: Tobyhanna Army Depot
2. Date of Submission: _____
3. Project Title: Aluminum Ion Vapor Deposition (AIVD)
4. Description of Project Objective: Determine least costly process for coating steel parts.
5. Alternative: AIVD
6. Economic Life: 20 years

8. Program / Project Costs						
7. Project Year	a. Non-Recurring		b. Recurring	c. Annual Cost	d. Discount Factor	e. Discounted Annual Cost
	R & D	Investment	Operations			
0			\$0	\$0	1.000	\$0
1	\$0	\$750,082	\$251,003	\$1,001,085	0.986	\$987,452
2			\$166,790	\$166,790	0.960	\$160,037
3			\$166,790	\$166,790	0.933	\$155,678
4			\$166,790	\$166,790	0.908	\$151,438
5			\$166,790	\$166,790	0.883	\$147,313
6			\$166,790	\$166,790	0.859	\$143,301
7			\$166,790	\$166,790	0.836	\$139,398
8			\$166,790	\$166,790	0.813	\$135,601
9			\$166,790	\$166,790	0.791	\$131,908
10			\$166,790	\$166,790	0.769	\$128,315
11			\$166,790	\$166,790	0.748	\$124,820
12			\$166,790	\$166,790	0.728	\$121,420
13			\$166,790	\$166,790	0.708	\$118,113
14			\$166,790	\$166,790	0.689	\$114,896
15			\$166,790	\$166,790	0.670	\$111,766
16			\$166,790	\$166,790	0.652	\$108,722
17			\$166,790	\$166,790	0.634	\$105,761
18			\$166,790	\$166,790	0.617	\$102,880
19			\$166,790	\$166,790	0.600	\$100,078
20			\$166,790	\$166,790	0.584	\$97,352
21			\$166,790	\$166,790	0.568	\$94,701
9.						
	Totals	\$0	\$750,082	\$3,586,803	\$4,336,885	\$3,480,951

- 10a. Total Project Cost (discounted) \$3,480,951
- 10b. Uniform Annual Cost (without terminal value) (9e. / 9d.) \$205,532
11. Less Terminal Value (discounted) \$0
- 12a. Net Total Project Cost (discounted) (10a. - 11.) \$3,480,951
- 12b. Uniform Annual Cost (with terminal value) (12a. / 9d.) \$205,532

**SUMMARY OF COSTS FOR ECONOMIC ANALYSIS/
PROGRAM EVALUATION STUDIES
FORMAT A
SENSITIVITY ANALYSIS III**

1. Submitting DoD Component: Tobyhanna Army Depot
2. Date of Submission: _____
3. Project Title: Aluminum Ion Vapor Deposition (AIVD)
4. Description of Project Objective: Determine least costly process for coating steel parts.
5. Alternative: Status Quo (present)
6. Economic Life: 20 years

8. Program / Project Costs						
7. Project Year	a. Non-Recurring		b. Recurring	c. Annual Cost	d. Discount Factor	e. Discounted Annual Cost
	R & D	Investment	Operations			
0			\$0	\$0	1.000	\$0
1			\$251,003	\$251,003	0.986	\$247,585
2			\$251,003	\$251,003	0.960	\$240,841
3			\$251,003	\$251,003	0.933	\$234,281
4			\$251,003	\$251,003	0.908	\$227,900
5			\$251,003	\$251,003	0.883	\$221,693
6			\$251,003	\$251,003	0.859	\$215,654
7			\$251,003	\$251,003	0.836	\$209,780
8			\$251,003	\$251,003	0.813	\$204,067
9			\$251,003	\$251,003	0.791	\$198,508
10			\$251,003	\$251,003	0.769	\$193,102
11			\$251,003	\$251,003	0.748	\$187,842
12			\$251,003	\$251,003	0.728	\$182,726
13			\$251,003	\$251,003	0.708	\$177,749
14			\$251,003	\$251,003	0.689	\$172,907
15			\$251,003	\$251,003	0.670	\$168,198
16			\$251,003	\$251,003	0.652	\$163,616
17			\$251,003	\$251,003	0.634	\$159,160
18			\$251,003	\$251,003	0.617	\$154,825
19			\$251,003	\$251,003	0.600	\$150,608
20			\$251,003	\$251,003	0.584	\$146,506
21			\$251,003	\$251,003	0.568	\$142,515
9.	Totals	\$0	\$0	\$5,271,063	16.936	\$4,000,063

10a. Total Project Cost (discounted)	\$4,000,063
10b. Uniform Annual Cost (without terminal value) (9e. / 9d.)	\$236,183
11. Less Terminal Value (discounted)	\$0
12a. Net Total Project Cost (discounted) (10a. - 11.)	\$4,000,063
12b. Uniform Annual Cost (with terminal value) (12a. / 9d.)	\$236,183

**SUMMARY OF COSTS FOR ECONOMIC ANALYSIS/
PROGRAM EVALUATION STUDIES
FORMAT A
SENSITIVITY ANALYSIS III**

1. Submitting DoD Component: Tobyhanna Army Depot

2. Date of Submission: _____

3. Project Title: Aluminum Ion Vapor Deposition (AIVD)

4. Description of Project Objective: Determine least costly process for coating steel parts.

5. Alternative: AIVD

6. Economic Life: 20 years

8. Program / Project Costs							
7. Project Year	a. Non-Recurring		b. Recurring	c. Annual Cost	d. Discount Factor	e. Discounted Annual Cost	
	R & D	Investment	Operations				
0			\$0	\$0	1.000	\$0	
1	\$0	\$750,082	\$251,003	\$1,001,085	0.986	\$987,452	
2			\$185,646	\$185,646	0.960	\$178,130	
3			\$185,646	\$185,646	0.933	\$173,278	
4			\$185,646	\$185,646	0.908	\$168,559	
5			\$185,646	\$185,646	0.883	\$163,968	
6			\$185,646	\$185,646	0.859	\$159,502	
7			\$185,646	\$185,646	0.836	\$155,157	
8			\$185,646	\$185,646	0.813	\$150,931	
9			\$185,646	\$185,646	0.791	\$146,820	
10			\$185,646	\$185,646	0.769	\$142,821	
11			\$185,646	\$185,646	0.748	\$138,931	
12			\$185,646	\$185,646	0.728	\$135,147	
13			\$185,646	\$185,646	0.708	\$131,466	
14			\$185,646	\$185,646	0.689	\$127,885	
15			\$185,646	\$185,646	0.670	\$124,402	
16			\$185,646	\$185,646	0.652	\$121,013	
17			\$185,646	\$185,646	0.634	\$117,717	
18			\$185,646	\$185,646	0.617	\$114,511	
19			\$185,646	\$185,646	0.600	\$111,392	
20			\$185,646	\$185,646	0.584	\$108,358	
21			\$185,646	\$185,646	0.568	\$105,407	
9.	Totals	\$0	\$750,082	\$3,963,923	\$4,714,005	16.936	\$3,762,847

10a. Total Project Cost (discounted)	\$3,762,847
10b. Uniform Annual Cost (without terminal value) (9e. / 9d.)	\$222,176
11. Less Terminal Value (discounted)	\$0
12a. Net Total Project Cost (discounted) (10a. - 11.)	\$3,762,847
12b. Uniform Annual Cost (with terminal value) (12a. / 9d.)	\$222,176

Appendix H

Work Order for Installation of an AIVD System at TOAD

DRAFT

**WORK ORDER FOR
ALUMINUM ION VAPOR DEPOSITION
AT TOBYHANNA ARMY DEPOT**

Prepared by

**IT Corporation
Cincinnati, Ohio**

**Contract No. DACA31-91-D-0074
Task Order No. 3
IT Project No. 322244**

**USAEC COTR
Mr. Edward G. Engbert**

**USAEC Project Engineer
Mr. James Heffinger**

**U.S. Army Environmental Center
Aberdeen Proving Ground, Maryland**

July, 1994

Draft
Work Order for Installation of
Aluminum Ion Vapor Deposition System at Tobyhanna Army Depot

I.Project Scope

- A. The aluminum ion vapor deposition system will be installed at the Tobyhanna Army Depot in Building 1B, Bay 1.
- B. The system will consist of the following components:
 - a 12' long x 6' diameter vacuum chamber
 - a roughing pump/blower (with oil demister)
 - a diffusion pump
 - a holding pump
 - a polycold cryopump
 - a control console
 - a high-voltage power supply
 - a parts rack
 - a dual-barrel accessory
 - a water cooling system
 - an argon cylinder
 - a grit blasting booth
 - a glass peening booth, and
 - assorted valves and gauges.
- C. Ancillary system requirements include the following:
 - air
 - electric
 - water
 - a smooth floor
 - an air conditioned room
 - a roof vent, and
 - lighting.

DRAFT

II.Scopes of Work

- A. The scope of work for the aluminum ion vapor deposition contractor includes the following:
 - install the equipment

- initial start-up of the equipment

B. The scope of work for the Tobyhanna Army Depot includes the following:

- building an air conditioned room with the following requirements:

- a. All walls shall be wood framing, insulated, sheet rocked, and painted white.
- b. All doors shall have 1/2 glazing, lock sets, panic hardware on insides, closers and sweeps.
- c. All ceiling heights shall be 10' dropped, 2' x 4' grid with meltaway block.
- d. All lighting shall be white fluorescent, flush mounted in dropped grid (fixtures shall have four 4' bulbs and be capable of utilizing only 2 or all 4) unless otherwise noted. Intensity shall be 100 footcandles at work height (30").
- e. All incoming air (through vent grills) shall be pre-filtered through 30% efficiency filters.
- f. All rooms shall be equipped with 110 VAC, 60 Hz, convenience receptables located per National Electric Code.
- g. A level (to 1/4" in 5'0" or better), smooth (no cracks or grooves), with epoxy coating surface floor.
- h. Air conditioning requirements: 70 degrees F +/- 2 degrees F
- i. Relative humidity requirements: 50% +/- 5%
- j. An exhaust vent consisting of a 4" PVC exhaust duct from the vacuum pump and filtration and collection units through the roof ventilator located on the roof. A drip leg shall be installed to prevent moisture from reentering the pump.

- provide the following utilities to the aluminum ion vapor deposition system

- a. Electrical: 480 Volt, 3 Phase, 60 Hertz, 300 Amp to the Power Supply Unit through 3" diameter or larger conduit.
- b. Air (for chamber): Compressed air, 3/4" standard pipe, 60-80 psig regulated line pressure with a water and particulate filter and lubricator. Self-draining water collectors should be used.

(for transport dolly): Compressd air, 60-80 psig, 40' long x 1/2" air hose with quick-release coupling for each transport dolly. A hose hanger hook nearby.

- c. Water: 40 psig, < 80 deg F, 24 gpm, 1-1/4" pipe
- d. Argon: Bottle of welding quality compressed argon gas regulated through a dual-stage regulator to 25 psig. 3.0 SCFH.
- e. Nitrogen: Clean, dry, gaseous nitrogen, 300 cfm at 25 psig at a temperature between 32°F and 80°F.

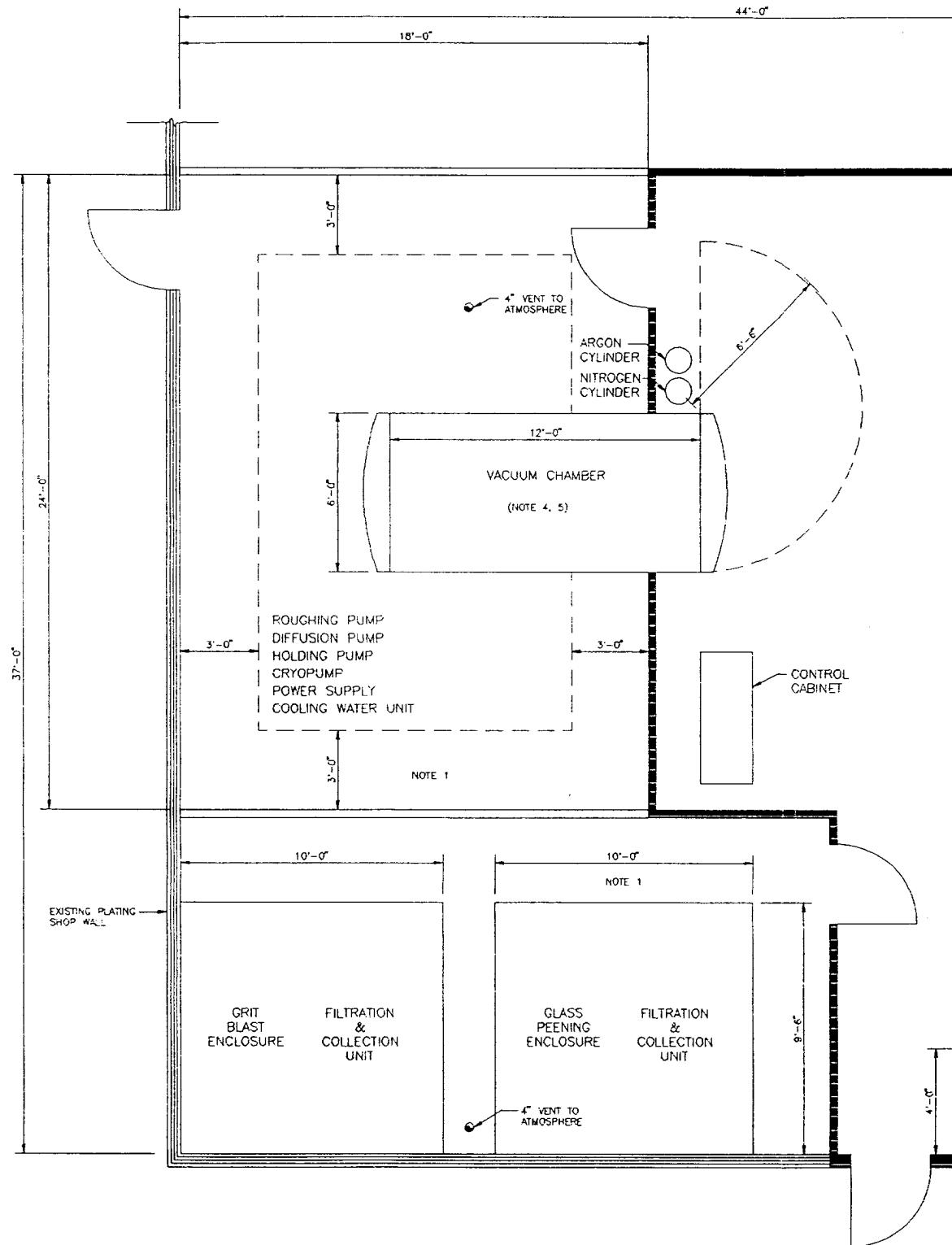
- Provide the following utilities to the glass bead peening booth:

- a. Electrical: 460 V, 3 phase, 60 hertz, 3 amps
110 V, 1 phase, 60 hertz, 6 amps
- b. Air: 1" NPT, 70 CFM at 80 psig

- Provide the following utilties to the grit blasting booth:

- a. Electrical: 460 V, 3 phase, 60 hertz, 3 amps
110 V, 1 phase, 60 hertz, 6 amps
- b. Air: 1" NPT, 70 cfm at 80 psig

III. A diagram for the proposed floor plan is shown in Figure I.



FLOOR PLAN

SCALE: 3/8' = 1'-0"

DRAWING ISSUES		
REV	DATE	BY
1	05/23/94	MSN

RS FOR INTERNAL REVIEW

LEGEND:

 LIMITS OF AREA TO BE AIR CONDITIONED

NOTES:

1. THE FLOOR LOADING LIMIT OF THE AREA WHERE THE ION VAPOR DEPOSITION SYSTEM IS TO BE INSTALLED IS 1,000 POUNDS PER SQUARE FOOT.
2. THE ION VAPOR DEPOSITION SYSTEM OPERATING ROOM TO BE AIR CONDITIONED FOR HUMIDITY CONTROL. REFER TO WORK ORDER FOR RELATIVE HUMIDITY REQUIREMENT.
3. PREPARE FLOOR OF ROOM ACCORDING TO REQUIREMENT SPECIFIED IN WORK ORDER.
4. CHAMBER HEIGHT SET BY USING INTERNAL RAIL HEIGHT ABOVE FLOOR TO MATCH HEIGHT OF PARTS PACK ON STANDARD RACK TRANSPORT DOLLY.
5. LOCATE INTAKE AIR FOR CHAMBER VACUUM RELEASE INSIDE AIR CONDITIONED ROOM. PROVIDE MUFFLER ON AIR INTAKE.

PROJECT NAME
ALUMINUM ION VAPOR DEPOSITION SYSTEM
FOR TOBYHANNA ARMY DEPOT

SHEET TITLE
PROPOSED FLOOR PLAN

IT INTERNATIONAL
TECHNOLOGY
CORPORATION
11499 CHESTER ROAD
CINCINNATI, OHIO 45246

SCALE: 3/8" = 1'-0"	SHEET NO. 1
DRWNS:	MSN
FPL:	322244.03.03
DTR:	05-23-94
DOC NO.:	9406FP01.DWG

1

1 OF 1

CONTROL CABINET

PLAN

